THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

www.epemag.com

ULTRASONIC GARAGE PARKING ASSISTANT

- No more fender benders at home!
- Touch-sensitive colour screen
- Precise ultrasonic sensing
- Dynamic colour-coded display

WIN A MICROCHIP Dual Mode PICtail Board

HOTEL SAFE ALARM Scare uninvited light-fingered visitors!

100dB STEREO LED AUDIO LEVEL/VU METER – PART 1

Add some eye-catching bling to your Hi-Fi!

NEW SERIES

Teach-In 2017

Introducing the BBC micro:bit Part 1: Meet the micro:bit

AUDIO OUT, PIC n' MIX, INGENUITY UNLIMITED, TECHNO TALK, CIRCUIT SURGERY & NET WORK

JUNE 2017 £4.65

06

9 770262 361195

FUZE

FUZE Special Edition

- Protect your Pi from physical & static damage
- UK keyboard & Mouse
- FUZE I/O Board with 40 way GPIO pass-through
- Clearly labelled input output ports
- 3 Amp power supply and on/off switch!
- Adds analogue ports, 4 in & 1 out
- 840 pin solderless breadboard (black)
- 8GB SD pre-configured with FUZE BASIC

THE NATIONAL MUSEUM OF COMPUTING "The FUZE is what the Raspberry Pi was designed for"

micro mart EDITOR'S CHOICE ... it's certainly the best we've ever tested

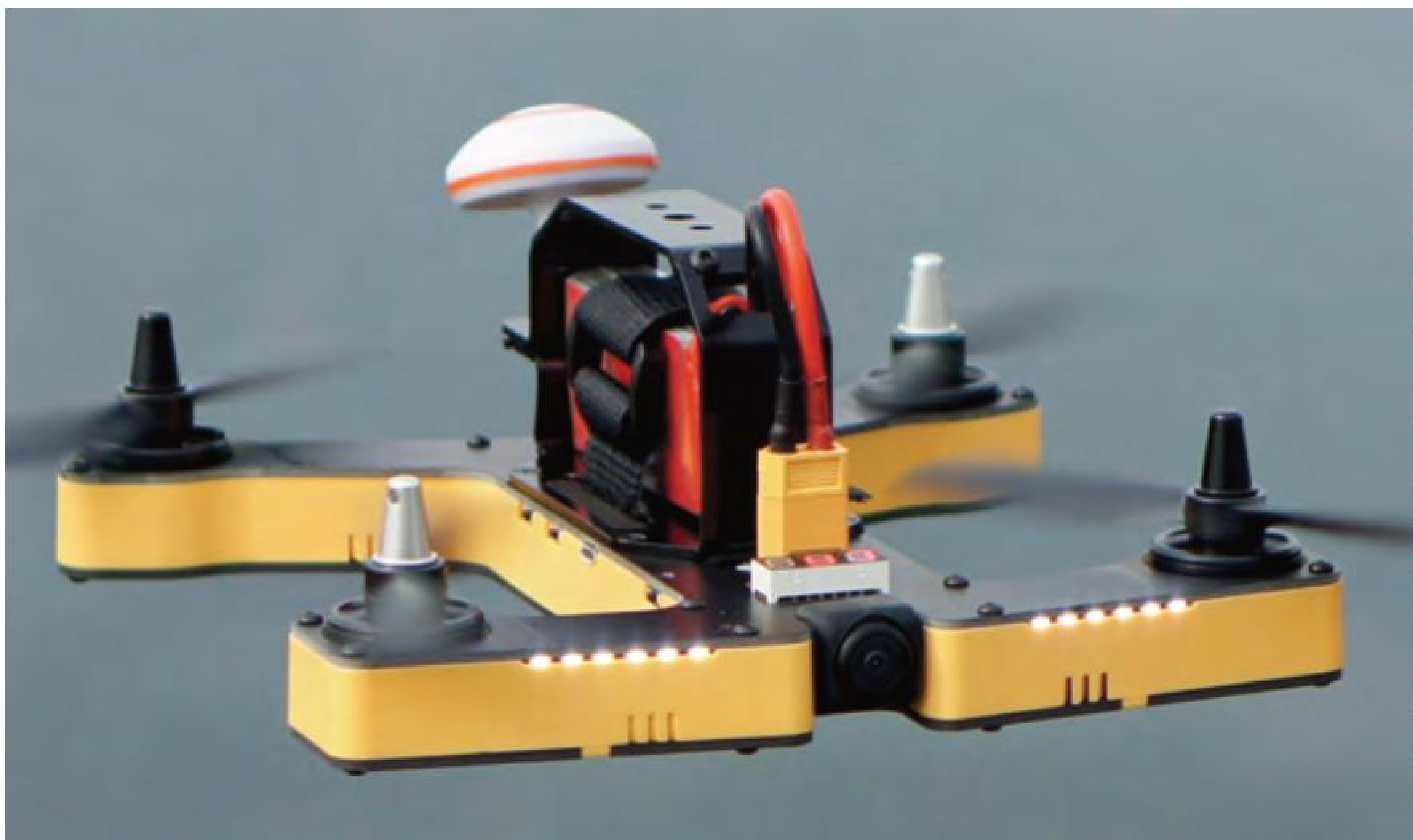
PC PRO Recommended ...makes the Pi more accessible than ever

from £99.99

FUZE Technologies Ltd
+44 (0) 1844 239 432 - contact@fuze.co.uk

Available from www.fuze.co.uk

QUICKDRONES



- 100% ready to fly. From box to air takes seconds
- Unified body design & incredibly durable
- 700TVL camera provides excellent FPV picture
- 2205 2300KV powerful motor
- Status LED to show battery & transmission channel
- One button to switch video channel & power
- DVR port for onboard recording
- Low battery & out of sight warning buzzer
- Available in various colours

The *VIFLY* R220 is a 100% ready-to-fly FPV Racing Drone, no assembly, no calibration, just fly it out of the box. The robust design protects the electrical components inside the frame and gives it an incredible ability to withstand violent crashes. The 3 digit LED display shows the battery voltage and a single button switches video transmission channel and power output. The addition of a DVR port and warning buzzer, makes flying the VIFLY R220 FPV drone easier than ever.

price £349.99

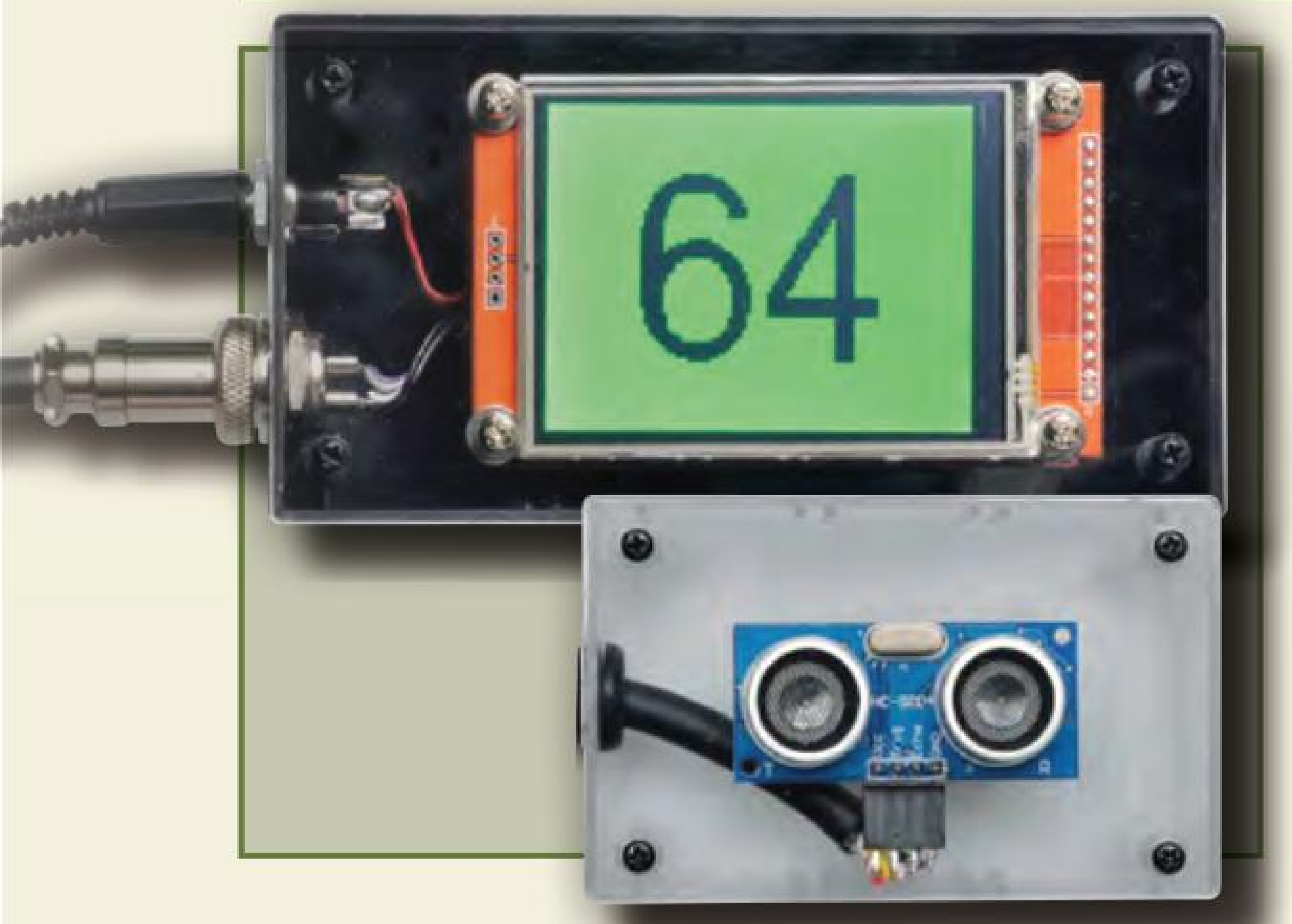
Including VAT and UK delivery

BinaryDistribution Ltd
+44 (0) 1844 239 432 - admin@binarydistribution.co.uk

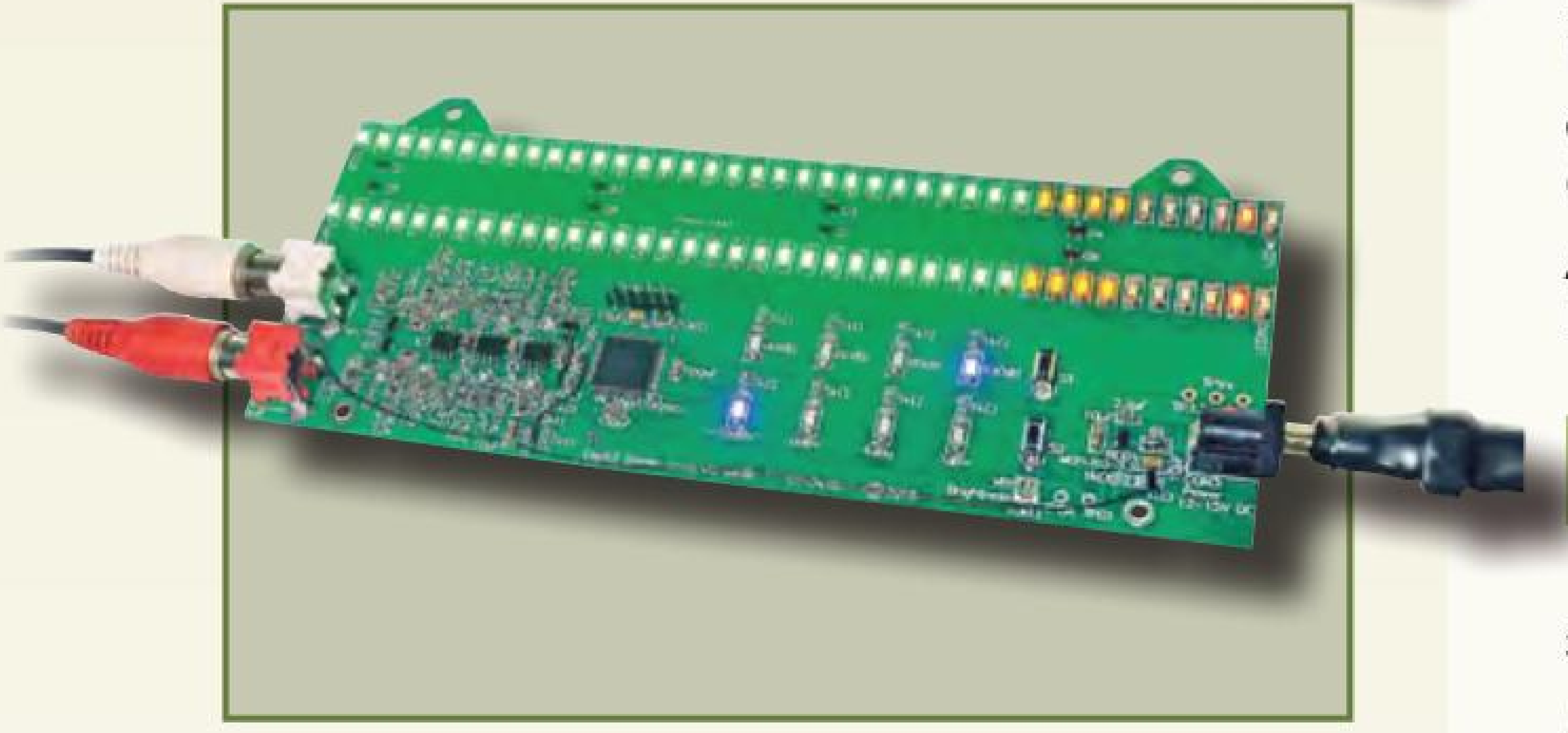
www.quickdrones.co.uk

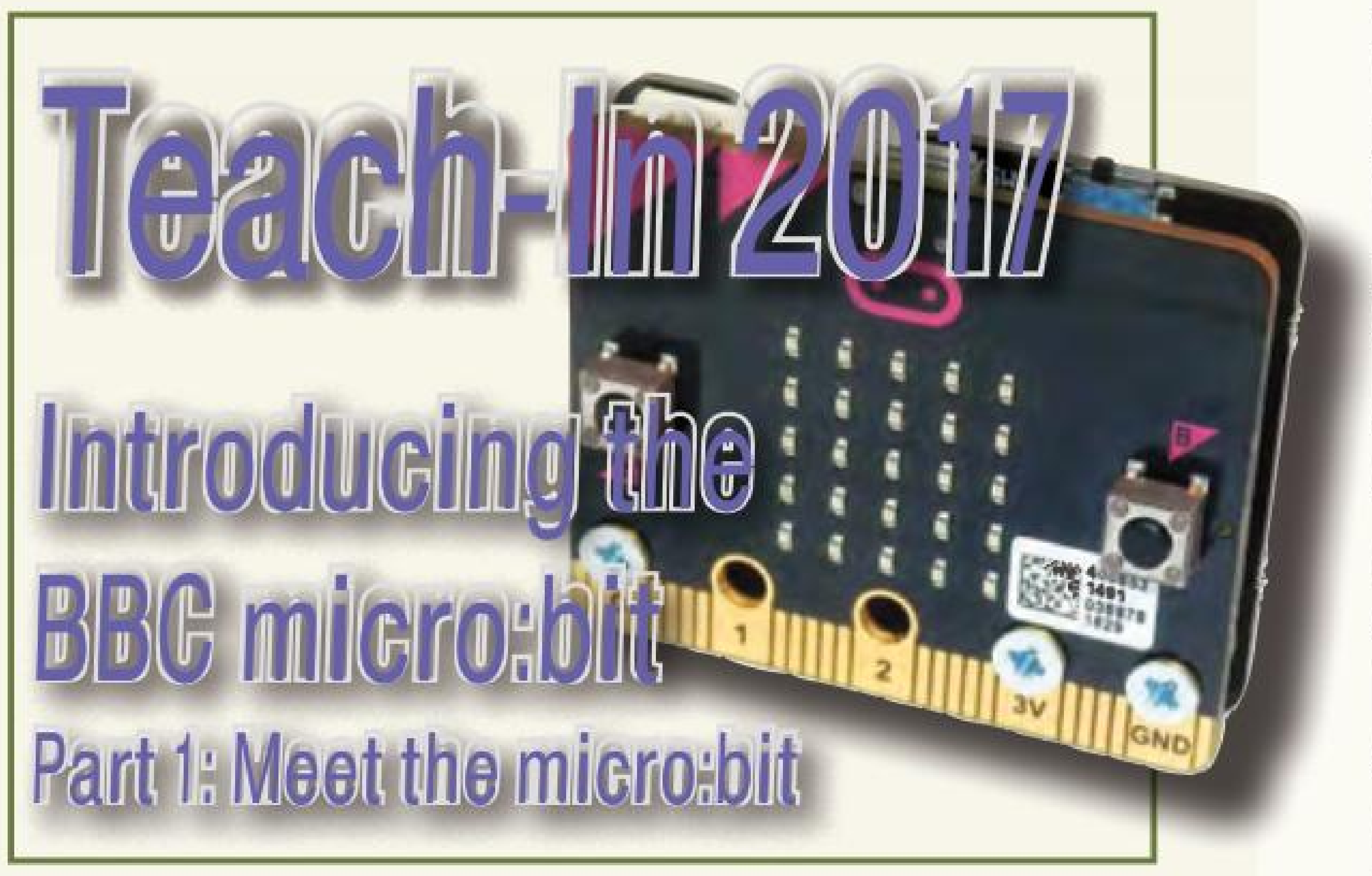
ISSN 0262 3617
● PROJECTS ● THEORY ●
● NEWS ● COMMENT ●
● POPULAR FEATURES ●
VOL. 46. No 6 June 2017

EPE EVERYDAY PRACTICAL ELECTRONICS
INCORPORATING ELECTRONICS TODAY INTERNATIONAL
www.epemag.com



Hotel Safe Alarm
Unauthorised Opening
Door Open/ Alarm Pending
Enter Code
1
2
SAFE ALARM





© Wimborne Publishing Ltd 2017. Copyright in all drawings, photographs and articles published in *EVERYDAY PRACTICAL ELECTRONICS* is fully protected, and reproduction or imitations in whole or in part are expressly forbidden.

Our July 2017 issue will be published on Thursday 1 June 2017, see page 72 for details.

Projects and Circuits

ULTRASONIC GARAGE PARKING ASSISTANT 12
by Geoff Graham
This project makes positioning your car a breeze! You will always know just how many centimetres you are from the wall or an ideal stopping point.

HOTEL SAFE ALARM 20
by John Clarke
Check if your room's safe has been opened in your absence and give offenders a very bad feeling that he or she has been detected.

100dB STEREO LED AUDIO LEVEL/VU METER 28
by Nicholas Vinen
Give your Hi-Fi system some *WOW* factor with this spectacular Stereo VU Meter!

INGENUITY UNLIMITED 60
Minimal-component logic probes

Series and Features

TECHNO TALK by Mark Nelson 11
When tech goes bad

TEACH-IN 2017 – INTRODUCING THE BBC micro:bit 38
by Mike Tooley
Part 1: Meet the micro:bit

NET WORK by Alan Winstanley 44
Mission Impossible... Gadgets galore... Dashcams and Facebook
Smarter spearphishing

PIC n' MIX by Mike O'Keeffe 47
PICs and the PICkit 3: A beginner's guide – Part 11

CIRCUIT SURGERY by Ian Bell 50
Oscilloscope probes

AUDIO OUT by Jake Rothman 56
MX50 power amplifier kit – Part 2

Regulars and Services

SUBSCRIBE TO *EPE* and save money 4

***EPE*–MICROCHIP SPECIAL OFFER – NOT TO BE MISSED!** 5

EDITORIAL 7
What it says on the tin... Hell is tech support

NEWS – Barry Fox highlights technology's leading edge 8
Plus everyday news from the world of electronics

MICROCHIP READER OFFER 26
EPE Exclusive – Win a Microchip Dual Mode PICtail Board

***EPE* BACK ISSUES CD-ROM** 27

***EPE* TEACH-IN 8** 43

***EPE* CD ROMS FOR ELECTRONICS** 63
A wide range of CD-ROMs for hobbyists, students and engineers

DIRECT BOOK SERVICE 66
A wide range of technical books available by mail order, plus more CD-ROMs

***EPE* PCB SERVICE** 70
PCBs for *EPE* projects

ADVERTISERS INDEX 71

NEXT MONTH! – Highlights of next month's *EPE* 72

Readers' Services • Editorial and Advertisement Departments *7*

Quasar Electronics Limited
PO Box 6935, Bishops Stortford
CM23 4WP, United Kingdom
Tel: 01279 467799
Fax: 01279 267799
E-mail: sales@quasarelectronics.co.uk
Web: www.quasarelectronics.co.uk

All prices INCLUDE 20.0% VAT. Free UK delivery on orders over £35
Postage & Packing Options (Up to 0.5Kg gross weight): **UK Standard 3-7 Day Delivery** - £3.95; **UK Mainland Next Day Delivery** - £8.95; **Europe (EU)** - £12.95; **Rest of World** - £14.95 (up to 0.5Kg).
Order online for reduced price Postage (from just £3)
Payment: **We accept all major credit/debit cards. Make PO's payable to Quasar Electronics Limited.**
Please visit our online shop now for full details of over 1000 electronic kits, projects, modules and publications. Discounts for bulk quantities.

01279 **Card Sales & Enquiries** **467799**

Solutions for Home, Education & Industry Since 1993

PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £9.95
18Vdc Power supply (661.130UK) £23.95
Leads: Parallel (LDC136) £2.56 | Serial (LDC441) £2.75 | USB (LDC644) £2.14

PIC Programmer & Experimenter Board

Great learning tool. Includes programming examples and a reprogrammable 16F627 Flash Microcontroller. Test buttons & LED indicators. Software to compile & program your source code is included. Supply: 12-15Vdc. Pre-assembled and ready to use.
Order Code: VM111 - ***~~£38.88~~ £30.54***

USB PIC Programmer and Tutor Board

The only tutorial project board you need to take your first steps into Microchip PIC programming using a PIC16F882 (included). Later you can use it for more advanced programming. Programs all the devices a Microchip PICKIT2® can! Use the free Microchip tools for PICKit2™ & MPLAB® IDE environment.
Order Code: EDU10 - ***£46.74***

ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. 16Vdc.
Kit Order Code: 3123KT - ***~~£32.95~~ £21.95***
Assembled ZIF: AS3123ZIF- ***~~£48.96~~ £37.96***

USB /Serial Port PIC Programmer

Fast programming. Wide range of PICs supported (see website for details). Free Windows software & ICSP header cable. USB or Serial connection. ZIF Socket, leads, PSU not included.
Kit Order Code: 3149EKT - ***~~£49.96~~ £29.95***
Assembled Order Code: AS3149E - ***£44.95***
Assembled with ZIF socket Order Code: AS3149EZIF - ***~~£74.96~~ £49.95***

PICKit™2 USB PIC Programmer Module

Versatile, low cost, PICKit™2 Development Programmer. Programs all the devices a Microchip PICKIT2 programmer can. Onboard sockets & ICSP header. USB powered.
Assembled Order Code: VM203 - ***£39.54***

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code 660.446UK £10.68

USB Experiment Interface Board

Updated Version! 5 digital inputs, 8 digital outputs plus two analogue inputs and two analogue outputs. 8 bit resolution. DLL.
Kit Order Code: K8055N - ***~~£39.95~~ £22.74***
Assembled Order Code: VM110N - ***£39.95***

2-Channel High Current UHF RC Set

State-of-the-art high security. Momentary or latching relay outputs rated to switch up to 240Vac @ 12 Amps. Range up to 40m. 15 Tx's can be learnt by one Rx. Kit includes one Tx (more available separately). 9-15Vdc.
Kit Order Code: 8157KT - ***£44.95***
Assembled Order Code: AS8157 - ***£49.96***

Computer Temperature Data Logger

Serial port 4-ch temperature logger. °C/°F. Continuously log up to 4 sensors located 200m+ from board. Choice of free software applications downloads for storing/using data. PCB just 45x45mm. Powered by PC. Includes 1xDS1820 sensor.
Kit Order Code: 3145KT - ***~~£19.95~~ £16.97***
Assembled Order Code: AS3145 - ***£22.97***
Additional DS1820 Sensors - ***£4.96 each***

8-Channel Ethernet Relay Card Module

Connect to your router with standard network cable. Operate the 8 relays or check the status of input from anywhere in world. Use almost any internet browser, even mobile devices. Email status reports, programmable timers... Test software & DLL online.
Assembled Order Code: VM201 - ***£134.40***

Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - ***£17.95***
Assembled Order Code: AS3179 - ***£24.95***

Many items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix)

Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/5A) in both the forward and reverse directions. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections. PCB: 90x42mm.
Kit Order Code: 3166KT - ***£19.95***
Assembled Order Code: AS3166 - ***£25.95***

8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our free Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
Kit Order Code: 3108KT - ***£74.95***
Assembled Order Code: AS3108 - ***£89.95***

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ indoor range. 112 x 122mm. Supply: 12Vdc/500mA
Kit Order Code: 3142KT - ***~~£64.96~~ £59.96***
Assembled Order Code: AS3142 - ***£69.96***

Temperature Monitor & Relay Controller

Computer serial port temperature monitor & relay controller. Accepts up to four Dallas DS18S20 / DS18B20 digital thermometer sensors (1 included). Four relay outputs are independent of the sensors giving flexibility to setup the linkage any way you choose. Commands for reading temperature / controlling relays are simple text strings sent using a simple terminal or coms program (e.g. HyperTerminal) or our free Windows application. Supply: 12Vdc.
Kit Order Code: 3190KT - ***~~£79.96~~ £49.96***
Assembled Order Code: AS3190 - ***£59.95***

3x5Amp RGB LED Controller with RS232

3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone or 2-wire serial interface for microcontroller or PC communication with simple command set. Suits common anode RGB LED strips, LEDs, incandescent bulbs. 12A total max. Supply: 12Vdc. 69x56x18mm
Kit Order Code: 8191KT - ***£29.95***
Assembled Order Code: AS8191 - ***£29.95***

QUASAR electronics

velleman

cebek

Official UK Main Dealer

Stocking the full range of Cebek & Velleman Kits, Mini Kits, Modules, Instruments, Robots and more...

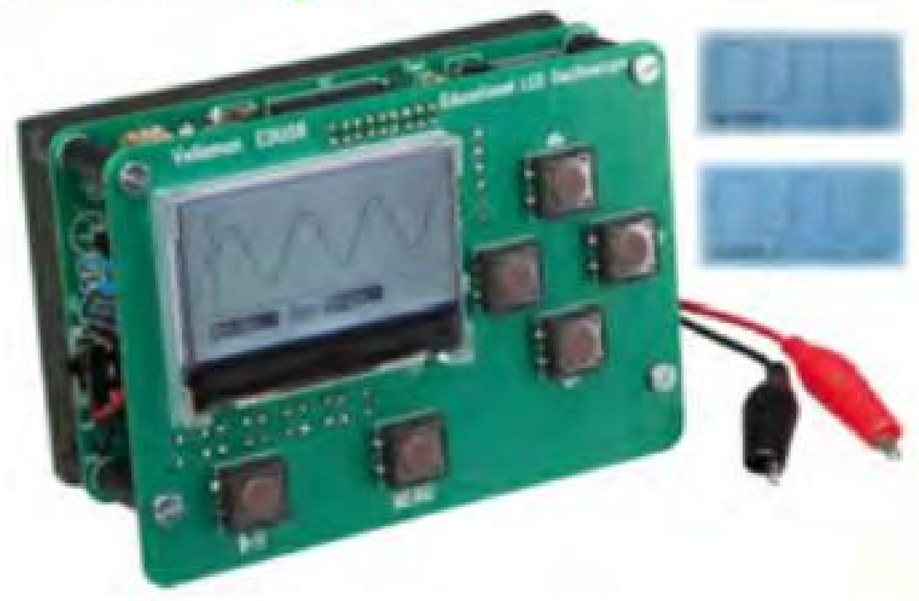
Card Sales & Enquiries 01279 467799

2-Ch WLAN Digital Storage Scope

Compact, portable battery powered fully featured two channel oscilloscope. Instead of a built-in screen it uses your tablet (iOS, Android™ or PC (Windows) to display the measurements. Data exchange between the tablet and the oscilloscope is via WLAN. USB lead included.

*Code: WFS210 - **£161.95** iinc VAT & Free UK Delivery*

LCD Oscilloscope Self-Assembly Kit



Build your own oscilloscope kit with LCD display. Learn how to read signals with this exciting new kit. See the electronic signals you learn about displayed on your own LCD oscilloscope. Despite the low cost, this oscilloscope has many features found on expensive units, like signal markers, frequency, dB, true RMS readouts. 64 x 128 pixel LCD display.

*Code: EDU08 - **£49.99** inc VAT & Free UK Delivery*

200 Watt Hi-Fi Amplifier, Mono or Stereo (2N3055)

Self-assembly kit based on a tried, tested and reliable design using 2N3055 transistors. Relay soft start delay circuitry. Current limiting loudspeaker protection. Easy bias adjustment. Circuit consists of two separate class AB amplifiers for a STEREO output of up to 100 Watts RMS @ 4Ω / channel or a MONO output of up to 200W @ 4Ω. Includes all board mounted components and large pre-drilled heatsink.

*Order Code 1199KT - **£69.95** inc VAT & Free UK delivery*

2MHz USB Digital Function Generator for PC

2MHz USB PC FUNCTION GENERATOR

Connect with a PC via USB. Standard signal waves like sine, triangle and rectangle available; other sine waves easily created. Signal waves are created in the PC and produced by the function generator via DDS (Direct Digital wave Synthesis). 2 equal outputs + TTL Sync output. Output voltage: 1mVtt to 10Vtt @ 600 Ohms.

*Code: PCGU1000 - **£161.95** inc VAT & Free UK delivery*

PC-Scope 1 Channel 32MS/s With Adapter

Oscilloscope
Spectrum Analyser
Transient Recorder

0Hz to 12MHz digital storage oscilloscope, using a computer and its monitor to display waveforms. All standard oscilloscope functions are available in the free Windows program supplied. Its operation is just like a normal oscilloscope. Connection is through the computer's parallel port, the scope is completely optically isolated from the computer port. Supplied with one insulated probe x1/x10.

*Code: PCS100A - **£124.91** inc VAT & Free UK Delivery*

2-Channel PC USB Digital Storage Oscilloscope

Pc-Lab2000SE
OSCILLOSCOPE
TRANSIENT RECORDER
SPECTRUM ANALYSER

Uses the power of your PC to visualize electrical signals. High sensitivity display resolution (down to 0.15mV), high bandwidth and sampling frequency up to 1GHz. Easy setup USB connection. No external power required! In the field measurements using a laptop have never been this easy. Stylish vertical space saving design. Powerful free Windows software.

*Code: PCSU1000 - **£246.00** inc VAT & Free UK Delivery*

Four Legged AllBot Kit

From the AllBot modular robot system with Arduino® compatible robot shields. Build and enhance the robot, learn how to program, use the app and have fun! Includes all necessary plastic parts, 4 x 9G servo motors, a servo motor connector shield (VRSSM), a battery shield (VRBS1).

*Code: VR408 - **£104.34** inc VAT & Free UK delivery*

PC USB Oscilloscope & Function Generator

Complete USB-powered Lab-in-a-Box! Free feature-packed software for two channel oscilloscope, spectrum analyser, recorder, function generator and bode plotter. With the generator, you can create your own waveforms using the integrated signal wave editor. For automated measurements, it is even possible to generate wave sequences, using file or computer RS232 input. 60MHz scope probe included

*Code: PCSGU250 - **£135.60** inc VAT & Free UK Delivery*

No.1 FOR KITS

www.QuasarElectronics.co.uk

Secure Online Ordering Facilities • Full Product Listing, Descriptions & Images • Kit Documentation & Software Downloads

E&OE

EVERYDAY PRACTICAL ELECTRONICS

UK readers you can SAVE £1.06 on every issue of *EPE*

How would you like to pay £3.59 instead of £4.65 for your copy of *EPE* ?

Well you can – just take out a one year subscription and save £1.06 an issue, or £12.80 over the year. You can even save £1.33 an issue if you subscribe for two years – a total saving of £32.10

Overseas rates also represent exceptional value

You also:

- **Avoid any cover price increase for the duration of your subscription**
- **Get your magazine delivered to your door each month**
- **Ensure your copy, even if the newsagents sell out**

Order by phone, or fax with a credit card, or by post with a cheque or postal order, or buy online from www.epemag.com (go to the Online Shop).

EVERYDAY PRACTICAL ELECTRONICS

SUBSCRIPTION PRICES

Subscriptions for delivery direct to any address in the UK: 6 months £23.50, 12 months £43.00, two years £79.50; Europe Airmail: 6 months £28.00, 12 months £52.00, 24 months £99.00; Rest Of The World Airmail: 6 months £37.00, 12 months £70.00, 24 months £135.00.

Cheques or bank drafts (in **£ sterling only**) payable to *Everyday Practical Electronics* and sent to EPE Subs. Dept., Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU. Tel: 01202 880299. Fax: 01202 843233. **Email:** subs@wimborne.co.uk. Also via the **Web** at: **www.epemag.com**.

Subscriptions start with the next available issue. We accept MasterCard, Maestro or Visa. (For past issues see the Back Issues page.)

ONLINE SUBSCRIPTIONS

Online subscriptions, for reading the magazine via the Internet, £19.99 for one year, visit **www.epemag.com** for more details.

SUBSCRIPTION ORDER FORM

☐ 6 Months: UK £23.50, Europe £28.00 (Airmail), Rest Of The World £37.00 (Airmail)
☐ 1 Year: UK £43.00, Europe £52.00 (Airmail), Rest Of The World £70.00 (Airmail)
☐ 2 Years: UK £79.50, Europe £99.00 (Airmail), Rest Of The World £135.00 (Airmail)

To: Everyday Practical Electronics,
Wimborne Publishing Ltd., 113 Lynwood Drive, Merley,
Wimborne, Dorset BH21 1UU
Tel: 01202 880299 Fax: 01202 843233
E-mail: subs@epemag.wimborne.co.uk

I enclose payment of £ .... (cheque/PO in £ sterling only), payable to *Everyday Practical Electronics*

☐ Please charge my Visa/Mastercard

My card number is: ....
Please print clearly, and check that you have the number correct

Signature ....

Card Security Code .... Valid From Date........................
(The last 3 digits on or just under the signature strip)

Card Ex. Date ....

Name ....

Address ....

Post code .... Tel. ....

Subscriptions can only start with the next available issue.

MasterCard VISA

EXCLUSIVE OFFER

Microchip and EPE have teamed up to bring you this AMAZING offer

MPLAB® IDE
Includes: MPLAB IDE, Documentation, Quick Reference Cards, Language Tool Demos, User Guides and Tutorials
MICROCHIP
PICkit 3
POWER
ACTIVE
STATUS

USUAL PRICE £68.64 (Inc VAT) (model DV164131)

The PICkit 3 allows debugging and programming of PIC and dsPIC Flash microcontrollers using the powerful graphical user interface of the MPLAB Integrated Development Environment (IDE). This kit includes the 44-pin demo board with a PIC18F45K20 microcontroller and a USB cable. Microchip's FREE MPLAB IDE software and the FREE Edition of the C Compiler provide a complete code development environment, and are available via free download from microchip.com

Spend over £125 on any of EPE's products, including subscriptions, and receive a PICkit 3 worth £68.64 for FREE

This offer is available to UK & overseas customers; however, for orders in Europe & ROW the following amounts will be added to cover postage:
£4.05 Europe: £5.10 ROW

Only 20 left, so hurry while stocks last!

Go to www.epemag.com to check availability

(Please note: subscriptions purchased with this offer cannot be cancelled before they expire; also, goods purchased with this offer can only be returned for exchange)

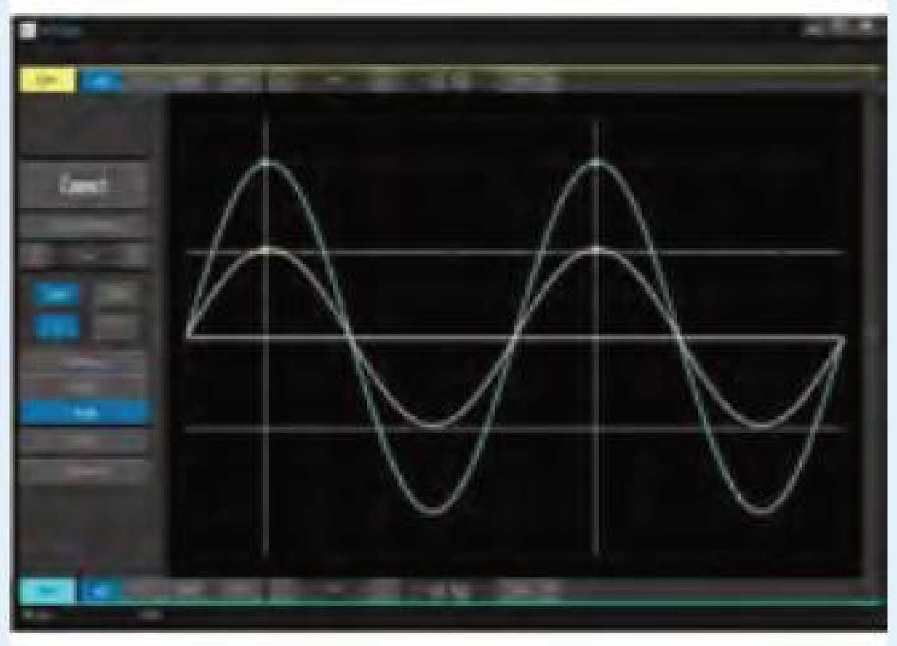
OFFER ONLY VALID WHILE STOCKS LAST – DON'T MISS OUT!!
JUST CALL 01202 880299 OR VISIT OUR SECURE ONLINE SHOP AT: www.epemag.com

MICROCHIP
www.microchipDIRECT.com

EPE EVERYDAY PRACTICAL ELECTRONICS

Sales: 0191 251 4363 www.TheElectronicsShop.co.uk

WFS210 2 Channel WLAN Scope



The Velleman WFS210 is the world's first WLAN dual channel digital storage oscilloscope geared towards tablet computers. A compact, portable battery powered fully featured. Instead of a built-in screen it uses your tablet (iOS, Android™ or PC(Windows)) to display the measurements. Data exchange between the tablet and the oscilloscope is via WLAN.

- High sensitivity: up to 0.2mV
- Full auto setup function
- Signal markers / Hold function
- DVM readouts
- Li-ion rechargeable battery included (3.7V 1800mAh)
- Input range: 5mV to 20V/div (12 steps)
- Timebase: 1μs to 1s/div
- Max. 30Vpp input
- Bandwidth: 2 x 10MHz (-3dB at selected ranges)
- Readouts: DC, AC+DC, True RMS, dBm, Vpp, Vmin, Vmax. Quote: EPEWFS

£79.20
Inc Delivery* & VAT

Offical Arduino Dealer
Genuine Arduino UNO R3
from £18.98+p&p
ARDUINO
Wide range of Boards,Shields & Accessories

HPS140MK2 Oscilloscope **£119.94**
Inc Delivery* & VAT

The HPS140MK2 handheld oscilloscope still holds the same power as its predecessor, but in a new and modern design. Although small in size, this oscilloscope packs 40 MS/s in real time and it's sensitivity can go as low as 0.1 mV. It also has a full automatic measuring system but can be operated manually if preferred.

- 40 Mega samples/sec in real time
- Bandwidth up to 10 MHz
- Full auto range option
- Signal markers for amplitude and time
- Memory hold function
- Direct audio power measurement
- Stylish OLED Display Quote: EPEHPS2

velleman

HPG1 Function Generator
velleman

A complete pocket function generator. Now you can take test signals on the move, 3 waveforms can be selected. Set the output voltage or frequency and select signal waveform using the on the screen menu. A powerful sweep function is also included.

* Frequency range: 1Hz to 1.000.000Hz
* Frequency steps: 1Hz, 10Hz, 100Hz, 1kHz and 10kHz
* Sine, square and triangle wave forms
* Runs on NiMH rechargeable battery pack (includeed)
* BNC Lead and Charger Included.
Quote: EPEHPG

WAVEFORM
FREQUENCY 1 000 Hz
STEP 1 000 Hz
1.474 Urms

£91.19
Inc Delivery* & VAT

2.4GHz Frequency Counter
0.01Hz to 2.4GHz
8 Digit LED Display
Gate Time: 100ms to 10s
2 Channel Operating mode
Power Supply: 110-220Vac 5W
Quote: EPE24G

velleman

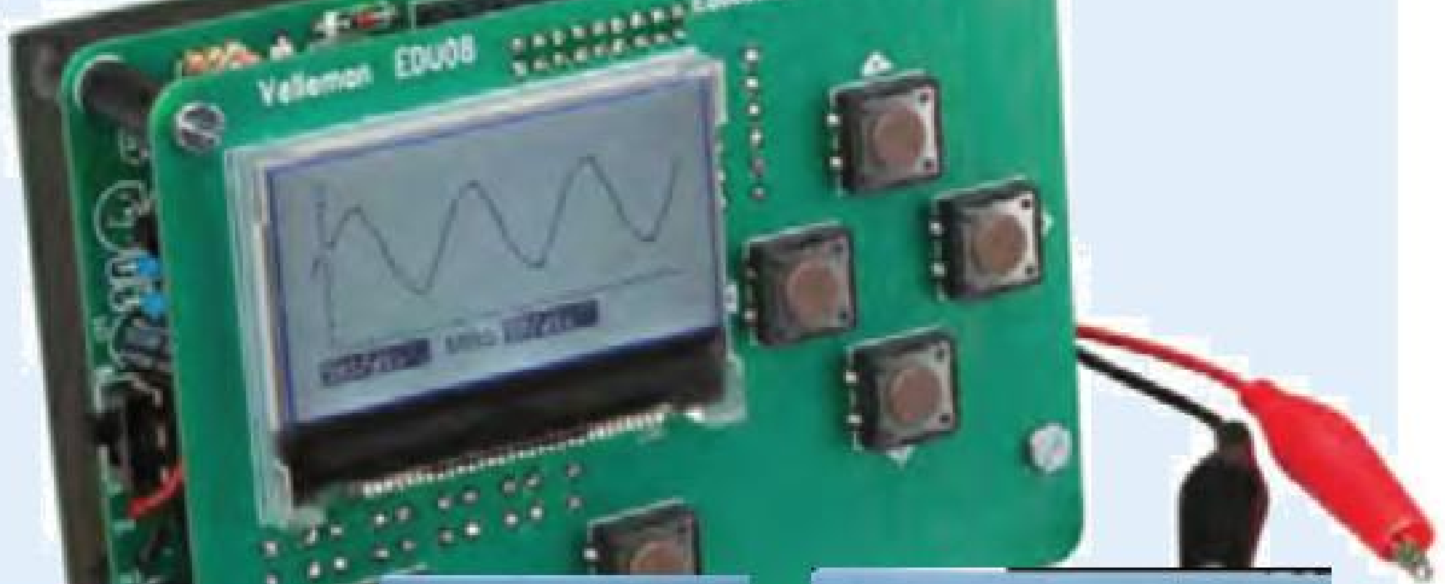
£81.00
Inc Delivery* & VAT

30V 5A Programmable PSU
Dual LED (Voltage & Current) Displays
Course & Fine Voltage /Current Adjustment
Volatge or Current Limiting.
* 5 Memories
* PC Link via USB or RS232
*Output:
0-30Vdc
0-5A

Quote: EPEPSU

£99.90
Inc Delivery* & VAT

Build your own Oscilloscope
A new self assembly kit, ideal for education and way to visualise signals. Features: Markers, Frequency, dB, True RMS readouts
Timebase range:
10μs-500ms/division (15 steps)
Input sensitvity:
100mV-5V/division (6 steps)
Max Input voltage: 30Vpp
Max Sample Rate:
1ms/s repetitive signal,
100ks/s real time signal
Dim: 80 x 115 x 40mm



£49.99
Inc Delivery* & VAT

Quote: EPESCOPE

ESR ELECTRONIC COMPONENTS
www.esr.co.uk

05/17

Tel: 0191 2514363
Fax: 0191 2522296
sales@esr.co.uk

ESR Electronic Components Ltd
Station Road,
Cullercoats, Tyne &
Wear. NE30 4PQ

Prices **INCLUDE** Delivery* & VAT.
*Delivery to any UK Mainland address, please call for delivery options for Highland & Island, Northern Ireland, Ireland, Isle of Man, Isle of Wight & Channel Islands

VOL. 46 No. 06 JUNE 2017

Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS
EDITORIAL Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: 01202 880299. **Fax:** 01202 843233.
Email: fay.kearn@wimborne.co.uk
Website: www.epemag.com
See notes on **Readers' Technical Enquiries** below – we regret technical enquiries cannot be answered over the telephone.

Advertisement Offices:
Everyday Practical Electronics Advertisements
113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: 01202 880299 **Fax:** 01202 843233
Email: stewart.kearn@wimborne.co.uk

Editor:	MATT PULZER
Subscriptions:	MARILYN GOLDBERG
General Manager:	FAY KEARN
Graphic Design:	RYAN HAWKINS
Editorial/Admin:	01202 880299
Advertising and Business Manager:	STEWART KEARN 01202 880299
On-line Editor:	ALAN WINSTANLEY
Publisher:	MIKE KENWARD

READERS' TECHNICAL ENQUIRIES
Email: fay.kearn@wimborne.co.uk
We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years' old. Letters requiring a personal reply must be accompanied by a stamped self-addressed envelope or a self-addressed envelope and international reply coupons. We are not able to answer technical queries on the phone.

PROJECTS AND CIRCUITS
All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

COMPONENT SUPPLIES
We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

ADVERTISEMENTS
Although the proprietors and staff of EVERYDAY PRACTICAL ELECTRONICS take reasonable precautions to protect the interests of readers by ensuring as far as practicable that advertisements are bona fide, the magazine and its publishers cannot give any undertakings in respect of statements or claims made by advertisers, whether these advertisements are printed as part of the magazine, or in inserts.

The Publishers regret that under no circumstances will the magazine accept liability for non-receipt of goods ordered, or for late delivery, or for faults in manufacture.

TRANSMITTERS/BUGS/TELEPHONE EQUIPMENT
We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment, as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

EPE EVERYDAY PRACTICAL ELECTRONICS

What it says on the tin

Mark Nelson's *Techno Talk* column has a spooky way of tapping into a number of tech-related preoccupations of mine, and this month has been no exception. His comments about the shoddy – would 'dishonest' be too much of a stretch? – service that some ISPs provide really struck home the day I received his email.

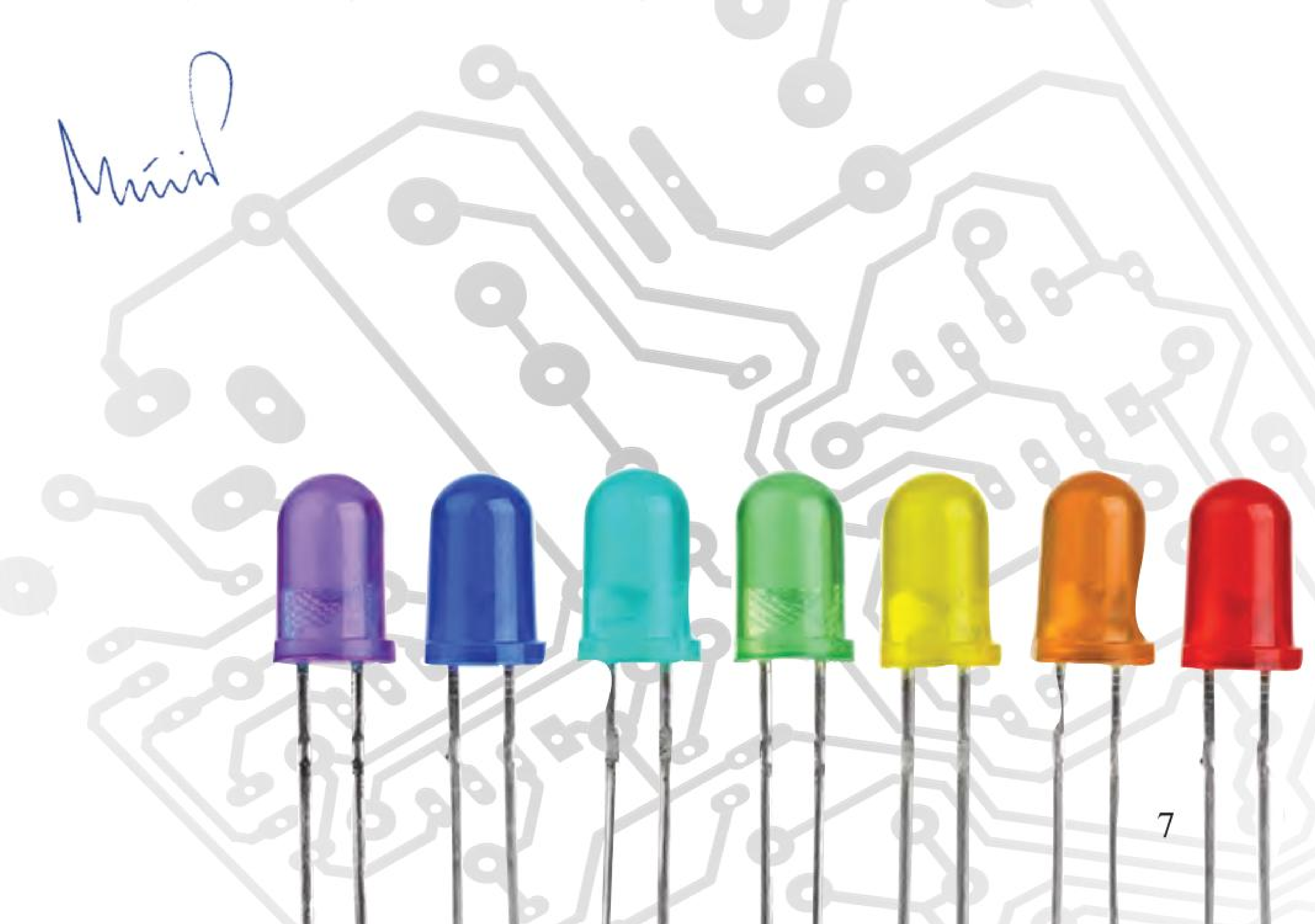
Like most of you, I depend very heavily on a reliable, fast broadband service. I work from home and need to send and receive large files on a regular basis. If I can't do that then working life very quickly becomes very difficult. For that reason I tend to prioritise quality and reliability over price and I don't mind paying a little over the odds for what I expect to be a bullet-proof connection.

Hell is tech support

To be fair to my ISP, most of the time my connection is reliable and fast, but every six months or so I get a problem that the ever-patronising recorded message, asking if I have 'tried turning it off and on' fails to fix. I'm then forced to contact my ISP. French existentialist philosopher Jean-Paul Sartre, at his misanthropic best, famously said that 'Hell is other people'. I'm not sure he'd make that claim today – hell is very definitely navigating the nightmare that is telephone tech support. Its myriad of dead-end options and cheery promises to 'direct you to the best available help' regularly reduces me to screaming obscenities at a deaf automaton. I do try and be civil to the underpaid staff in Manila and Bangalore, who have to deal with grumpy, stressed customers for eight-plus hours a day, but my patience very nearly snapped this week.

Having 'solved' my problem and got my system back online I was asked to perform a speed test, and when the result showed that I was now getting approximately a quarter of what I pay for, I objected. After some fiddling with settings in ISP-land I was up to half speed and told that was as good as it gets today, but I was promised connection speed would rise as 'things settled'. This more or less happened, although it took a good five days to return to my paid-for speed.

On the day of my call I was so grateful to be able to return to relative normality that I settled for half speed. This really is isn't good enough and I will be complaining. I urge you to do the same. The only way ISPs will get their act together and provide what we pay for is if customers pressure them – either directly or through OFCOM and legislation.



NEWS

A roundup of the latest Everyday News from the world of electronics

Hardware round-up – report *by Barry Fox*

When your PC absolutely, definitely has to work

Panasonic has been making rugged laptop PCs since 1996. The latest, the Toughbook CF-33, is a 2-in-1 device with detachable 12.5-inch screen and keyboard, so it can be used either as a laptop or tablet.

The CF-33 is weatherproof, surviving 30 minutes of water dunking, or a trip, naked, into space, and some pretty brutal dropping. (Although an integrated handle makes it less likely to be dropped.) The touchpad is pressure-sensitive, rather than capacitive, which makes it more use when the weather is wet.

In addition to all the usual ports (HDMI, SD-XC, USB, VGA, headset and LAN) there's one that will appeal to telecoms engineers – a native Serial RS232 socket (rather than USB-to-Serial converter) with all the pins individually addressable.

Power comes from twin batteries, which are hot swappable – so one battery can be changed while the other runs the device.

The CF-33 comes with Windows 10 Pro but can be 'downgraded' to Windows 7 Pro for those who want, need or simply prefer the older system. The downgrade option will, however, be available only until the end of October 2017, when Microsoft stops registering new devices.

The physical strength of the CF-33 does not come cheap, at 3552 euros plus VAT; and the Windows 7 downgrade costs another $100 for the additional royalty payment Panasonic must make to Microsoft.

A potentially very significant trademark application...

Registered trademarks can be a very powerful and valuable commercial weapon. They last for ever, if renewal fees are paid; Bass for Beer was the first UK trademark registered in January 1876 and is still in force. They give very strong protection – just try selling a drink labelled Coke or Pepsi and you will soon find out how strong.

Panasonic's latest 'Toughbook' – the CF-33

It's a basic principle of trademark law that you can't register an everyday dictionary word, but – if there are no objections – companies can sometimes monopolise surprising words. Bose succeeded in registering the word Lifestyle for audio equipment in the 1990s, which means other companies, which failed to object at the time, now have to steer clear of the label.

History is now repeating in the TV industry. Samsung recently applied to register the word 'HDR10', which is already being used to describe the 'Open' high dynamic range system built into most new 4K TV sets and BD players. The industry seems to have been taken unawares and is now wondering what to do or say.

John Higgins, director general of Digital Europe, the European body in Brussels which 'represents the digital technology industry in Europe', first said thanks 'for the alert' and then referred the hot potato to Digital Europe's communications and marketing director who said 'we have no comment on this subject'.

A spokeswoman for LG, traditionally Samsung's main rival, first said 'LG do not comment on rumours or speculation.'

When pointed to the official documents that detail Samsung's formal application, the spokeswoman said 'LG does not wish to comment.'

Ironically, LG has just issued a press release (20 March) which boasts that LG's 'entire 2017 line-up of premium TVs support the full palette of HDR formats… including… HDR10' – which is the very word for which Samsung wants exclusive rights. (See: **http://bit.ly/2p4lXlT** and **http://bit.ly/2pNQoNT**)

Hands-free brolly

And finally… news comes (and not on 1 April) of an 'Umbrella Drone to protect against wet weather'. Anyone with £1299 to spare can now pay drone e-tailer DronesDirect for the 'the perfect companion for this season's outings' and protection from 'the unpredictable British weather'

The 'exclusive and limited edition DJI Phantom 4 allows users to walk freely knowing they are shielded from overhead rainclouds by the drone-operated umbrella.'

Hardware round-up *continued*

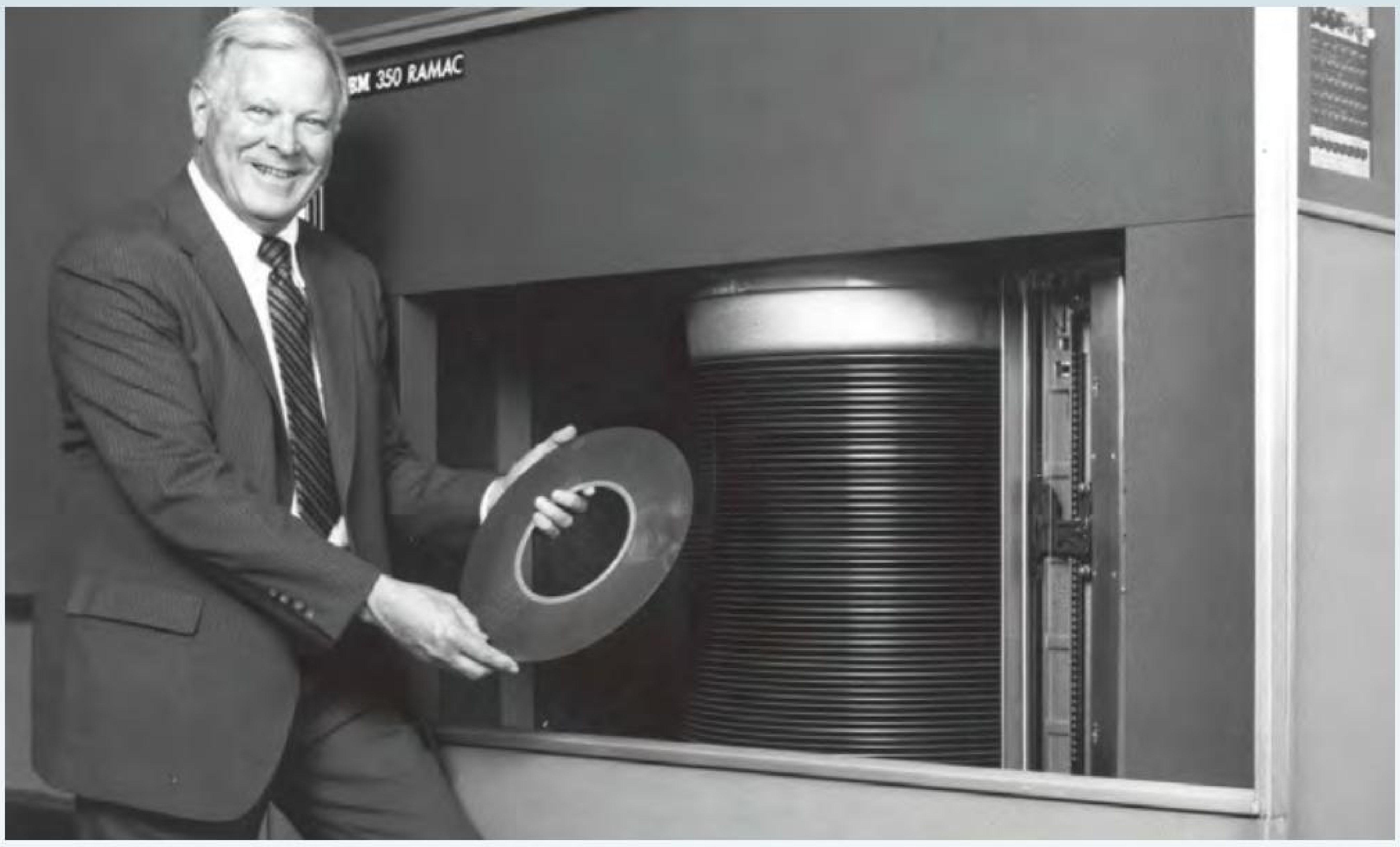
The device 'boasts advanced tracking technology which links to the GPS signal of a mobile phone', so that 'the flying umbrella will expertly navigate itself and track its owner's steps, sheltering them from each and every spring shower, so there is no need to operate it as you move.'

The Umbrella Drone has a 4K camera, for picturing the rain, and in-built intelligent collision avoidance technology.

Says Tim Morley, business unit manager at **DronesDirect.co.uk**: 'For those who don't want to be confined to staying indoors, who want to drone in changeable weather, and those who don't want to juggle managing an umbrella while carrying out their everyday tasks, then the innovative Umbrella Drone is a gadget not to be without. This is a truly clever and unique companion, which DronesDirect.co.uk is delighted to offer to consumers.'

Battery life is 'up to 30 minutes' – after which their proud owner presumably gets wet carrying a hands-free brolly home.

Single-atom magnetic storage breakthrough



The grandfather of all hard drives from 1956 – IBM's 350 RAMAC with 3.75MB of storage

In 1956, IBM announced the 350 RAMAC, the world's first magnetic hard drive. It had 50 24-inch platters and stored 3.75MB of data. It was complicated, sensitive and very expensive. It was also a breakthrough technology that more than sixty years later is still used in many computers the world over. Yes, Flash memory is steadily eating into its one-time monopoly, but as a technology it has proved to be incredibly resilient. Size and cost have shrunk dramatically and, of course, storage has rocketed by the million compared to IBM's wardrobe-sized original design.

The secret of the hard drive's success has been the extraordinary scalability of the medium. Engineers and physicists have done a remarkable job of squeezing evermore bits into a smaller and smaller area – and finding ways to read and write those bits reliably.

The core technology is defining minute areas of the drive's platter as bits that can be magnetised with one of two polarities, representing a logical 1 or 0. Currently, this basic real-estate storage unit is made up of roughly a million atoms, but researchers are much more ambitious and have now set their eyes on the ultimate in miniaturisation.

A recent report in the journal *Nature* explains how physicists created a stable magnetisable area from a single atom. Fabian Natterer, from the Swiss Federal Institute of Technology (EPFL) in Lausanne, who wrote the paper, described how 'single-atom magnets' were used to make an atomic hard drive. A rewritable device, made from two atoms was able to store a modest two bits of data. The Swiss team used holmium atoms at a temperature of less than 5K above absolute zero.

They wrote data with a pulse of current from the tip of a scanning tunnelling microscope, which flips the orientation of the atom's field between a 0 or 1. The atomic magnets proved stable, each retaining their data for several hours, with the team never seeing one flip unintentionally. They used the same microscope to read the bit – with different flows of current revealing the atom's magnetic state.

The technology is nowhere near commercialisation, but neatly shows just how far engineers are prepared to go to keep the hard drive show on the road.

Old bottles, new batteries

Researchers at the University of California, using waste glass bottles and a low-cost chemical process, have demonstrated lithium-ion batteries with nanosilicon anodes.

Silicon anodes can store ten-times more energy than graphite ones, but expansion/shrinkage during charge/discharge cycles make them unstable.

However, applying nanotechnology techniques to the silicon has reduced this problem. Using processed silicon dioxide and a cheap chemical reaction, the researchers created lithium-ion half-cell batteries that store almost four times more energy than conventional graphite anodes.

To create the anodes, the team crushed and ground bottles into a fine white power, then transformed the silicon dioxide into nanostructured silicon, and finally coated the silicon nanoparticles with carbon to improve stability and energy storage.

One glass bottle can provide enough nanosilicon for hundreds of coin cell batteries.

New PicoScope software

Pico Technology has added CAN FD decoding to its PicoScope 6 software. 'Our software could already decode a wide variety of serial protocols such as I^{2}C, SPI and UART, as well as automotive standards such as CAN, LIN and FlexRay,' said Trevor Smith, business development manager at Pico Technology. 'Now it can also decode CAN FD, which is the latest and fastest version of CAN Bus used in automotive and industrial applications.' More details at: **picotech.com**

King coal's day off

If you used mains electricity on Friday, 21 April 2017 then you helped make a little bit of power history – in the UK at least.

The industrial revolution started in Britain, and from the get go coal was the energy source that lifted industry from animal to machine power.

Coal first delivered mechanical power and then became the fuel of choice for generating electrical power. After the Second World War, coal's dominance was challenged by nuclear energy, gas and more recently renewable sources, especially offshore wind. However, coal continues to be used when other sources are unavailable or more expensive – but, according to the National Grid, 21 April was the first-ever 24-hour period when no coal at all was used to generate electricity in the UK.

microchip
DIRECT

microchipDIRECT
Memory Programming
We Can Now Program Memory Devices
BUY DIRECT
at
microchipDIRECT.com

microchipDIRECT offers access to the world's largest inventory of Microchip products and the most comprehensive online resource for pricing and support directly from Microchip Technology. We invite you as a valued Microchip customer to experience our service 24 hours a day, 7 days per week.

Visit www.microchipDIRECT.com and enjoy the confidence and convenience of buying from microchipDIRECT and take advantage of the following features:

- Direct stock from factory
- Direct customer service
- Secure ordering
- Volume pricing
- Credit lines
- Long-term orders and scheduling
- Programming and value add services
- Ability to adjust open orders
- Ship to your sites globally
- Online order status and notifications

microchip
DIRECT
www.microchipdirect.com

MICROCHIP

www.microchipDIRECT.com

The Microchip name and logo, the Microchip logo are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries. All other trademarks are the property of their registered owners.
© 2015 Microchip Technology Inc. All rights reserved. DS40001752B. MEC2010Eng04/15

When tech goes bad

Mark Nelson

Do you get the feeling that too many high-tech products and series reach the market long before they are ready for prime time, or without due regard to – or assured certainty of – whether they will deliver what they 'say on the tin'? If not, maybe this article will convince you!

IN THE PAST, NEW PRODUCTS were 'field tested' for several years before being unleashed on the public. Take the Trimphone, a telephone considered revolutionary back in the Swinging Sixties, with its trendy looks, modern colour options, glow-in-the-dark illuminated dial and electronic warbler that replaced a jangly bell. It was half the weight of the traditional type of telephone and came with a long lead and carry handle for extra mobility and convenience. Five years passed between its conception in 1961 and national launch in 1966, a delay considered entirely normal back in those risk-averse days. A trial of 1,000 prototypes in north-west London led to various design modifications and circuit improvements before Post Office Telecommunications considered the Trimphone fit and ready for national launch.

Fast forward to the present day

These days, product testing is left to customers – *after* the products have already been launched. Last October, Samsung took the decision to stop worldwide sales and shipments of its Galaxy Note 7 smartphone just weeks after launch, following reports that its lithium-ion batteries could explode while charging. In February of this year, news agencies reported how a woman flying to Australia from Beijing received a rude awakening when her music player batteries exploded, leaving her face and hands burned. The conflagration was so severe that the battery and its cover became stuck to the floor of the aircraft; passengers and crew endured the smell of melted plastic and singed hair for the remainder of the flight.

Not that this should come as a surprise of course. HP and Toshiba are among other manufacturers that have recalled products containing lithium-ion batteries during the past 12 months, despite widespread knowledge since 2006 that these power cells pose fire and explosion hazards that put people's lives in danger and have already claimed the life of a young child. On that basis, it's surprising that consumer protection organisations have not yet begun legal actions to prevent further sales of these potentially risky batteries.

Dodgy deals

In March, Sharon White, chief executive of communications regulator OFCOM, proclaimed 'a significant day for phone and broadband users,' after forcing BT's Openreach organisation to serve all customers equally. She continued: 'We will carefully monitor how the new Openreach performs, while continuing our work to improve the quality of service offered by all telecoms companies.'

This sounds laudable, but if OFCOM really wants to serve all users equally and fairly, then its next step should be to force all ISPs (Internet service providers) to deliver what they claim to. In other words, they should make the line speed quoted in their tariffs a condition of the contract with users. After that, OFCOM should enforce the contract legally and make providers reduce their charges on a per-individual-customer basis if they fail to deliver the quoted line speed.

I cannot think of any other consumer purchase where it is pot luck whether you get what you were told you'd be getting. Amazon cannot get away with selling you a 5TB hard drive that turns out to be only 2TB. A filling station cannot charge you for 20 litres of petrol and then supply you only 12 litres of diesel – so why should broadband providers be allowed to short-change their customers?

Fast radio from outer space

It appears that aliens from far-off galaxies can do a far better job at delivering wideband information than any Earthbound service provider – and they are managing this by radio means rather than optical fibres, coaxial cable or telephone wires. The only problem is that the signal from these 'fast radio bursts' last no longer than a millisecond, making it hard to decode the information content.

'Fast radio bursts are exceedingly bright given their short duration and origin at great distances, and we haven't identified a possible natural source with any confidence,' says Prof Avi Loeb of the Harvard-Smithsonian Center for Astrophysics in the US. 'An artificial origin is worth contemplating and checking,' he adds. Newly published research carried out by his team suggests that these mysterious phenomena could be evidence of advanced alien technology. Specifically, these bursts might be leakage from planet-sized transmitters powering interstellar probes in distant galaxies. Other scientists have detected mathematical patterns in the signals.

Loeb argues that the most plausible use of such power is driving interstellar light sails. The amount of power involved would be sufficient to push a payload of a million tons, or about 20 times the largest cruise ships on Earth. This is big enough to carry living passengers across interstellar or even intergalactic distances. Observers on Earth would see a brief flash because the sail and its host planet, star and galaxy are all moving relative to us. As a result, the beam sweeps across the sky and only points in our direction for a moment. Repeated appearances of the beam, which were observed but cannot be explained by cataclysmic astrophysical events, might provide important clues about its artificial origin. Using admirable understatement, Loeb admits that this work is 'speculative'.

Try this at home?

You too can monitor radio transmissions from outer space at home if you build your own antenna and receiver. The SETI League has fifteen hundred members in 60 countries on all seven continents who are devoted to the 'Search for Extraterrestrial Intelligence' by 'keeping alive the quest for our cosmic companions'. You can read how to build your own miniature version of Jodrell Bank at **www.setileague.org/articles/backyard.htm**, and you'll find plenty more about DIY radio astronomy by entering 'backyard radio astronomy' into Google. Better still, check out the September 2010 issue of this magazine, which included an excellent project for constructing a low-cost, easy-to-build receiver for signals from the planet Jupiter, no larger than a TV set-top box. And remember, if combining SETI and electronics appeals then you are in good company. Paul Horowitz, the famous Harvard-based co-author of the *Art of Electronics* is a long-time active supporter of SETI.

By Geoff Graham

Ultrasonic Garage Parking Assistant

This *Garage Parking Assistant* will display the distance from the back wall of your garage or carport to your car's bumper bar, in large digits and with a colour-coded background: green for go, yellow for slow down and red for stop. It makes positioning the car a breeze as you will always know just how many centimetres you are from the wall or an ideal stopping point.

THIS PROJECT is based on the *Micromite LCD BackPack* described in last month's *EPE*. The *BackPack* is a low-cost, touch-sensitive LCD panel coupled with an even lower-cost microcontroller programmed in BASIC. Turning this into our *Digital Garage Parking Assistant* only requires the addition of an ultrasonic distance sensor and a suitable BASIC program.

As you drive the car into the garage the display will light up, with the distance in centimetres displayed on a green background. As you come closer, the background changes to yellow and then finally to red. During this time, the display will tell you the exact distance to the wall or an ideal stopping point in large 25mm-high digits. Finally, after the vehicle has been stationary for a little while, the display blanks, ready for the next time you park the car.

By making some small changes to the software program, you could use the same design for other applications where you need to know the distance to an object. For example, with a simple modification, the unit could display the water level in a rainwater tank. Based on the dimensions of the tank, it could also calculate and display the content in litres, with the background

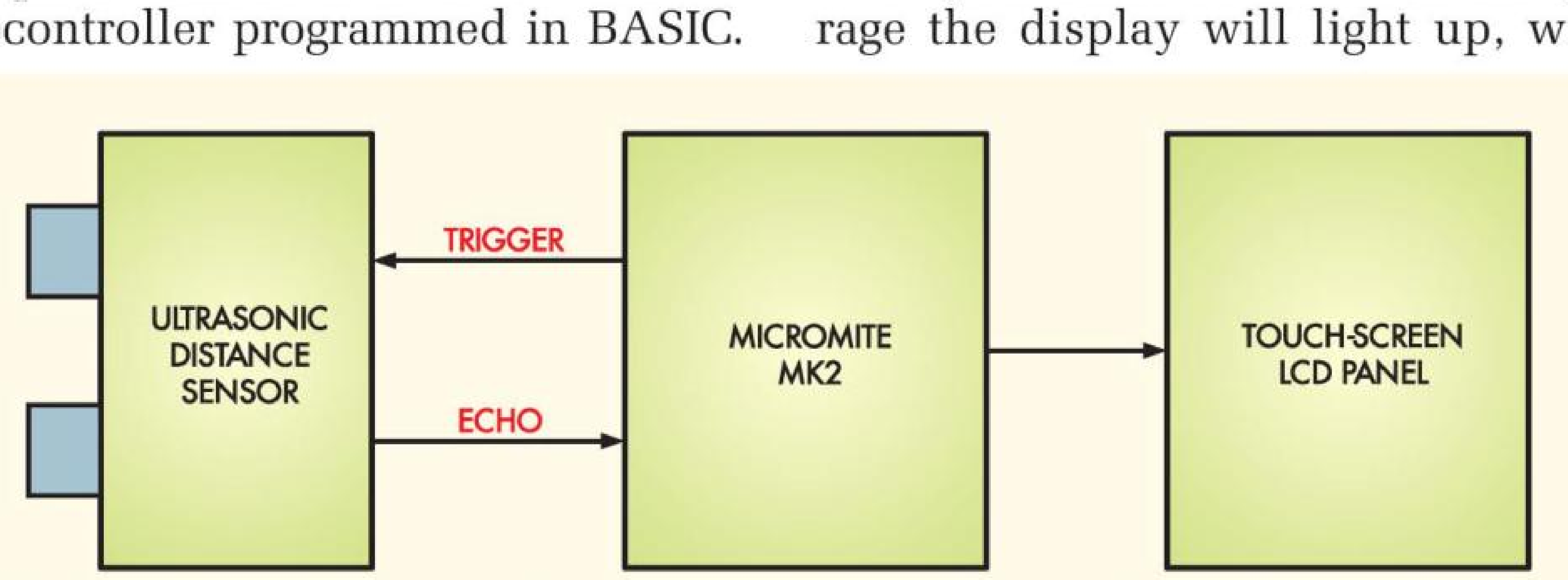
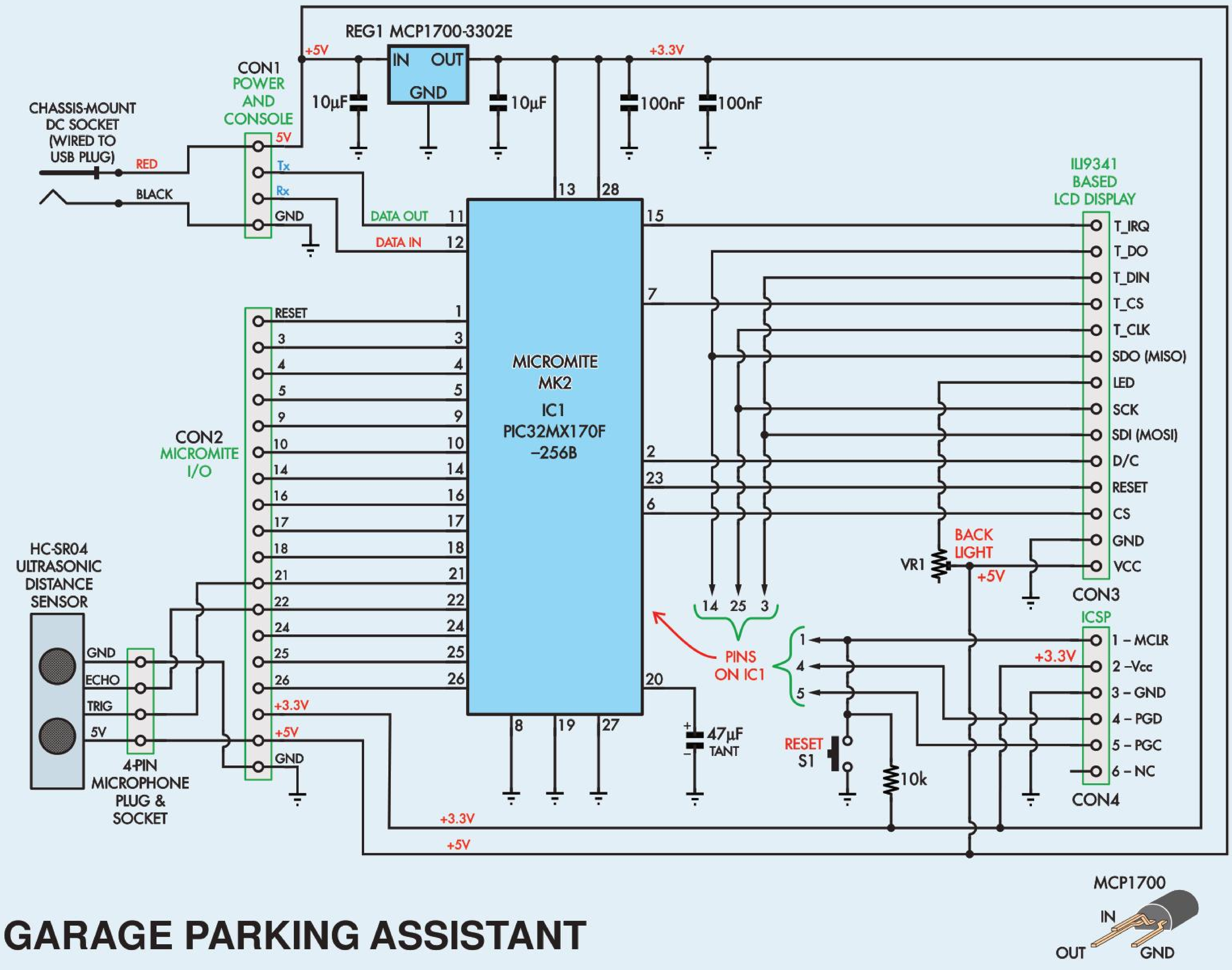


Fig 1: this block diagram shows the main components in the *Garage Parking Assistant*. The Micromite is in control: using the trigger line, it signals the ultrasonic distance sensor to transmit an ultrasonic sound pulse then measures the round trip time on the echo line. The result is converted to centimetres and displayed on the touch-screen LCD panel.


REG1 MCP1700-3302E
IN
OUT
GND
+5V
+3.3V
10µF
10µF
100nF
100nF
CON1
POWER AND CONSOLE
CHASSIS-MOUNT DC SOCKET (WIRED TO USB PLUG)
RED
BLACK
5V
Tx
Rx
GND
DATA OUT
DATA IN
11
12
13
28
15
7
MICROMITE MK2
IC1
PIC32MX170F –256B
2
23
6
20
8
19
27
CON2
MICROMITE I/O
RESET
3
4
5
9
10
14
16
17
18
21
22
24
25
26
+3.3V
+5V
GND
1
HC-SR04 ULTRASONIC DISTANCE SENSOR
GND
ECHO
TRIG
5V
4-PIN MICROPHONE PLUG & SOCKET
ILI9341 BASED LCD DISPLAY
T_IRQ
T_DO
T_DIN
T_CS
T_CLK
SDO (MISO)
LED
SCK
SDI (MOSI)
D/C
RESET
CS
GND
VCC
CON3
BACK LIGHT
VR1
+5V
14 25 3
PINS ON IC1
1
4
5
ICSP
1 – MCLR
2 –Vcc
3 – GND
4 – PGD
5 – PGC
6 – NC
CON4
+3.3V
47µF TANT
RESET S1
10k
+3.3V
+5V
MCP1700
IN
OUT
GND

GARAGE PARKING ASSISTANT

Fig.2: the circuit is based on a *Micromite LCD Backpack*, a touch-screen LCD and an ultrasonic distance sensor. IC1 does most of the work, while REG1 is a 3.3V voltage regulator. The ultrasonic distance sensor is triggered by pin 21 of the Micromite and the subsequent echo signal is then fed to pin 22. A 5V USB charger powers the circuit.

colours serving as a warning when the water has dropped to a low level.

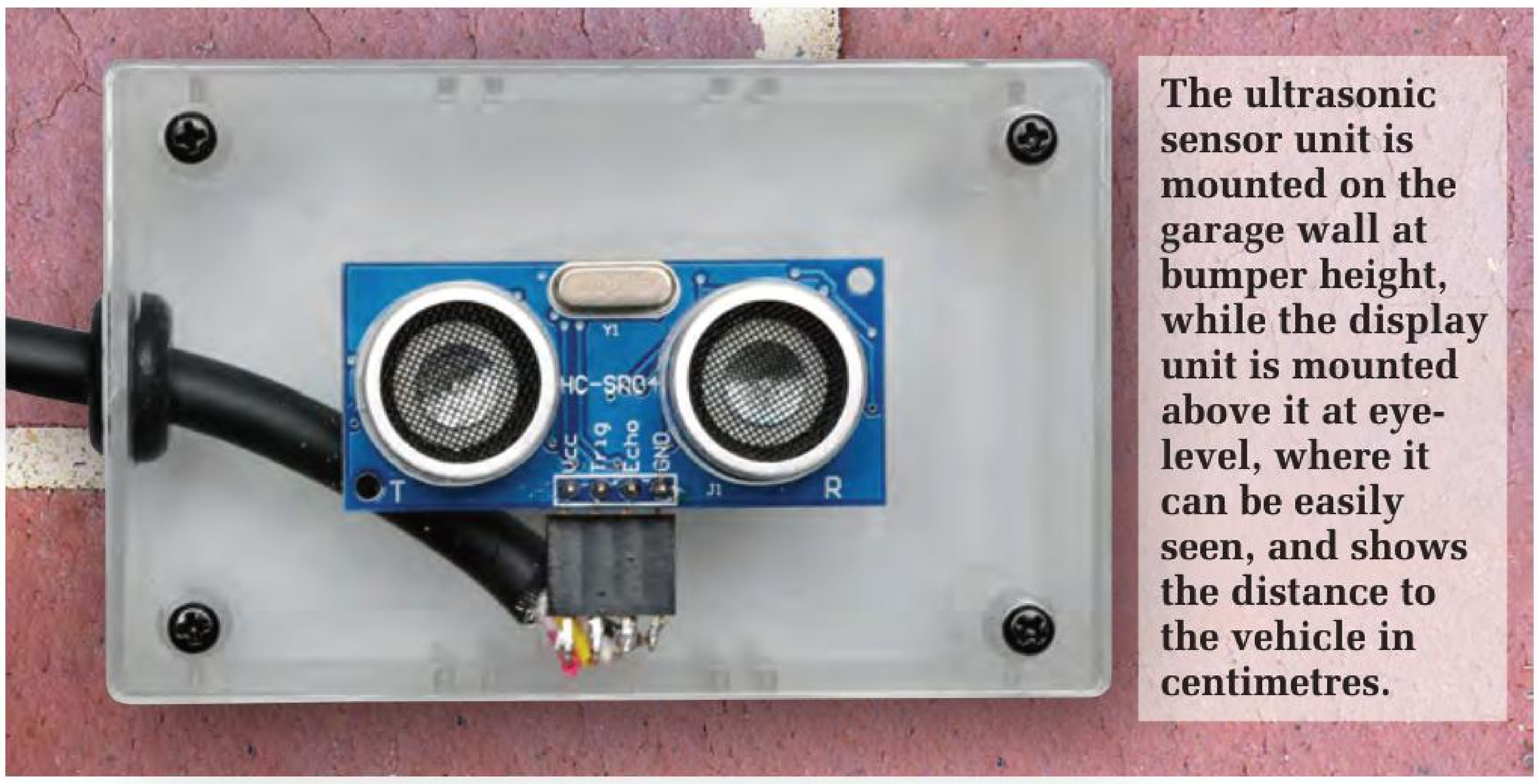
The program running on the *Digital Garage Parking Assistant* is written in BASIC. This is an easy-to-learn programming language and the program is stored in plain text. And because the Micromite has its own program editor, you can connect it to a laptop and easily change the program to suit your preferences, even when it is attached to the garage wall.

You might, for example, prefer the distance to be displayed in old-fashioned inches. That would require the modification of just one line in the program and could be done in minutes.

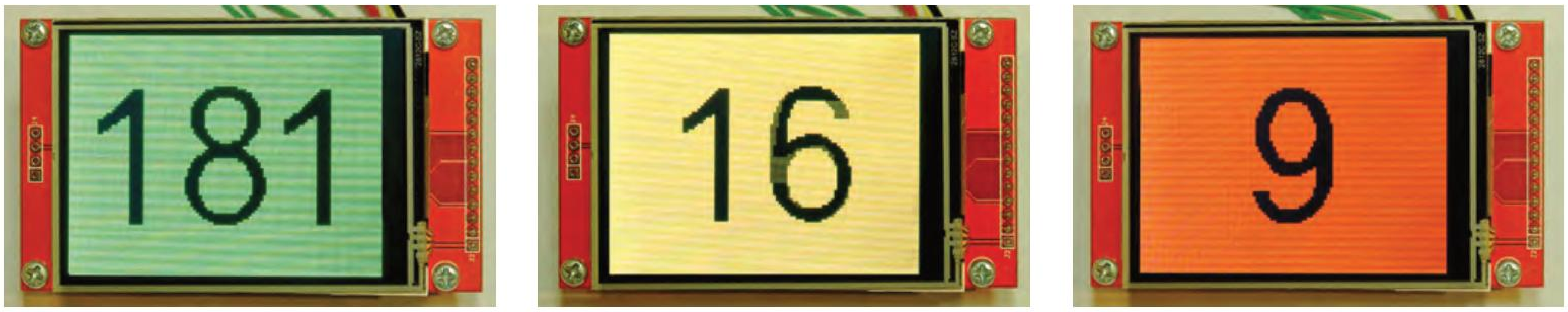
How it works

Fig.1 shows the block diagram of the *Garage Parking Assistant*, while Fig.2 shows the full circuit (including the LCD BackPack). The key components are an ultrasonic distance sensor, Micromite microcontroller IC1 and the LCD panel. The Micromite is completely in control; it uses the ultrasonic transducer to measure the distance and then displays the result on the LCD panel.

The distance sensor emits an ultrasonic pulse and listens for the return


HC-SR04
Y1
Vcc
Trig
Echo
GND
T
R
J1

The ultrasonic sensor unit is mounted on the garage wall at bumper height, while the display unit is mounted above it at eye-level, where it can be easily seen, and shows the distance to the vehicle in centimetres.



The background colours on the LCD provide a simple visual warning to the driver – green to continue, yellow to slow down and red to stop. In addition, the LCD shows the distance readout in centimetres. You can change the thresholds used for the three colours via the touch-screen and the various options menus.

echo, under the control of the Micromite. The microcontroller starts the measurement cycle by triggering the ultrasonic signal with a short positive pulse on the trigger line of the sensor. The sensor then raises the echo line to a logic-high level to acknowledge that it has sent the ultrasonic pulse and then drops it low again when the echo is received.

The time that the echo pin is held high by the sensor represents the round-trip time for the ultrasonic pulse to leave the sensor, reach the distant object and bounce back to the sensor. The microcontroller must accurately measure this time and then calculate the distance to the target.

In a normal microcontroller, this operation can be complex, but on the Micromite it's easy. The BASIC program just needs to use the `DISTANCE()` function, which will automatically generate the trigger pulse and calculate the distance to the target. The result is returned as a floating-point number representing the distance in centimetres to one decimal place.

R
J1
Trig
Echo
GND
T
T40
4.000

The ultrasonic distance sensor used in the *Garage Parking Assistant*. The righthand transducer is used to transmit the sound pulse and the lefthand transducer receives the reflected signal. The sensor will work with targets ranging from 30mm to 3m and is generally accurate to within a centimetre.

For example, if you had an ultrasonic transducer connected to pins 21 (trigger) and 22 (echo), the following command would display the distance (in centimetres) to the target:

```
PRINT DISTANCE(21, 22)
```

The output from running the above command would be a number. For example, 26.1 would mean that the distance is 26.1 centimetres.

The sensor will work with a target that ranges from 30mm to 3m. The precision will vary depending on several factors, such as the reflectivity of the object and the air temperature, but is generally accurate to within 10mm. This range and accuracy is more than adequate for our *Garage Parking Assistant*.

The ultrasonic sensor goes by the part number HC-SR04 and can be found on eBay. Compatible sensors are the SRF05, SRF06, Parallax PING and the DYP-ME007 (which is waterproof and therefore good for locations that are exposed to the weather). All of these work exactly the same as the HC-SR04.

The Micromite

The Micromite is a powerful but inexpensive controller. The IC used here is a 28-pin dual-in-line (DIL) package which can be plugged into an IC socket and is programmed using a version of BASIC called MMBasic.

BASIC stands for 'Beginner's All-purpose Symbolic Instruction Code'. Originally designed as an interactive teaching language by Dartmouth College in the US in 1963, it subsequently became widely used on early personal computers. Because of its simplicity, BASIC is often used for teaching the fundamental concepts of programming.

The program for the *Garage Parking Assistant* is written in BASIC and because of this, it can be easily modified to suit your preferences. For example, if you do not like the colours you can change them to suit yourself.

The Micromite is coupled with a low-cost touch-screen LCD panel which can display 320 by 240 pixels in any one of 65,535 colours. We chose the larger 2.8-inch version for our prototype because the displayed digits are easier to see from the driver's seat; they are just over 25.4mm (1-inch) high. If you already have the 2.4-inch LCD, this could be used instead. Its mounting arrangement (on the lid of the case) will be slightly different, however.

The *Garage Parking Assistant* uses the touch input to set its various options. All you need do is tap the screen and the main options menu appears.

Touch support is another area where the BASIC language makes programming easy. The `TOUCH()` function will return the X and Y coordinates of the touched location in pixels. Using this and a selection of drawing commands, it is possible to create touch-sensitive buttons and other screen objects that make sense to the casual user.

Options

The photo at top-right on the facing page shows the main options menu that appears when the screen is touched. In particular, it shows the timeout, offset and thresholds for the background colours.

The timeout is simply the length of time after the car has stopped moving before the display is blanked. By contrast, the offset is the distance from the sensor at which the displayed distance will be shown as zero. It is useful if the sensor is mounted on a wall, but the car must stop before the wall is reached, perhaps because of some other obstruction.

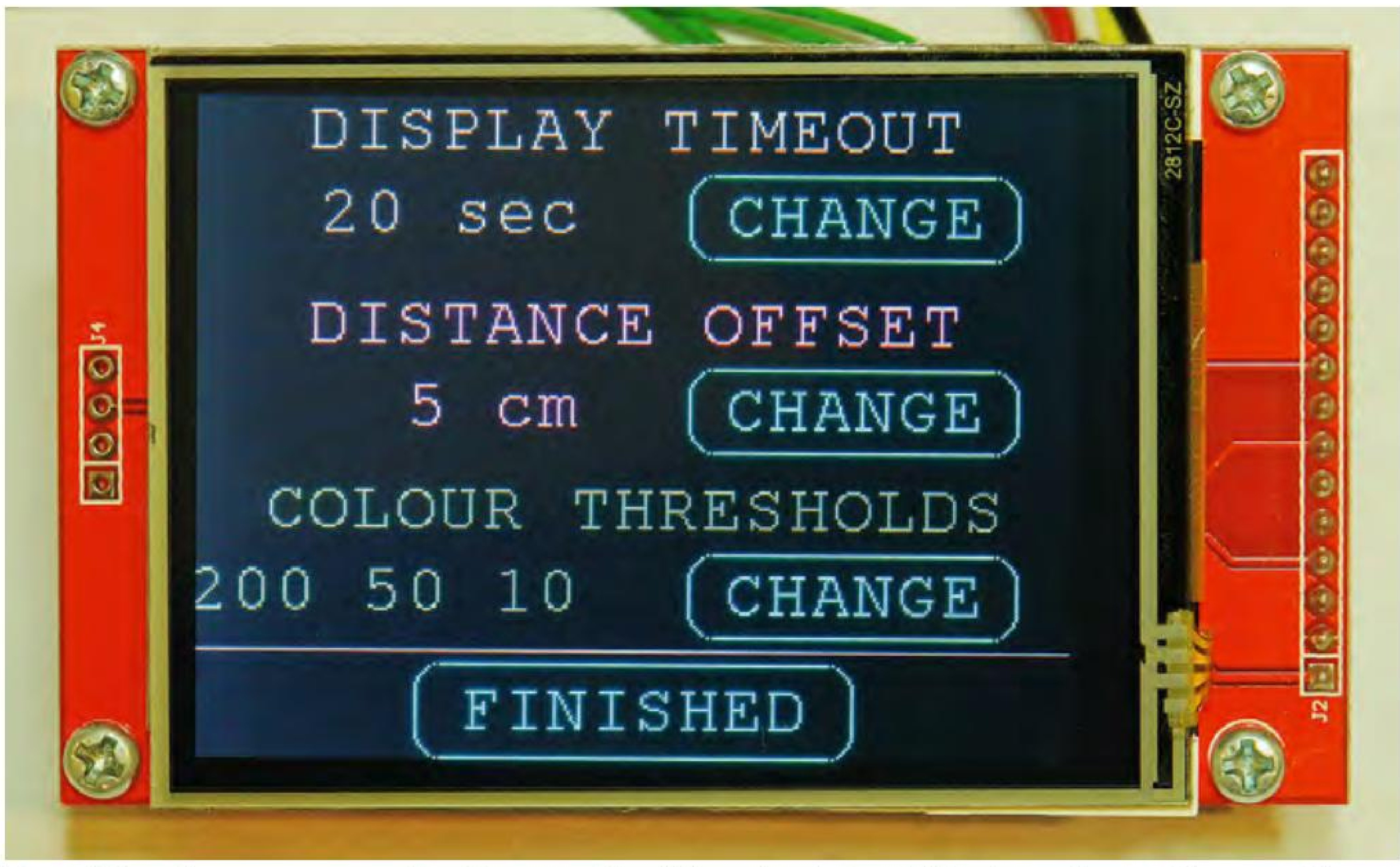
For example, if the offset is set at 10cm, the display will read zero when the distance between the car's bumper bar and the sensor has been reduced to 10cm.

Either of these two settings can be changed by touching the CHANGE button. In this case, a virtual on-screen keypad will be displayed which allows the required number to be keyed in. An example of this is shown in the photo below left. The keypad includes the ability to delete the previously entered digit (the DEL key) or cancel the entry and return to the menu (the CAN key). Pressing the ENT key will store the keyed-in number and return to the previous menu.

The third entry on the main options screen shows the thresholds for the colour changes. Pressing the change button for this entry will open up a new menu, as shown in the photo below right. **By default, the threshold for green is 200cm, for yellow it is 50cm and for red it is 10cm.**

Initially, as the vehicle approaches, the LCD will be blank, but when the vehicle's distance reaches the green threshold, the display will light and show the distance with a green background. Similarly, when the yellow threshold is reached, the background will change to yellow and so on.

These colour changes provide a simple visual warning for the driver – yellow means slow down and red means stop immediately. **You can easily change these thresholds by touching the CHANGE button and keying in the new number.**



DISPLAY TIMEOUT
20 sec
DISTANCE OFFSET
5 cm
COLOUR THRESHOLDS
200 50 10

Touching the screen on the *Garage Parking Assistant* displays the options settings. This photo shows the main menu, which displays the current settings for the timeout, the offset and the thresholds. Touching the CHANGE button for a particular parameter brings up a virtual keypad (see photo below) so that the setting can be changed.

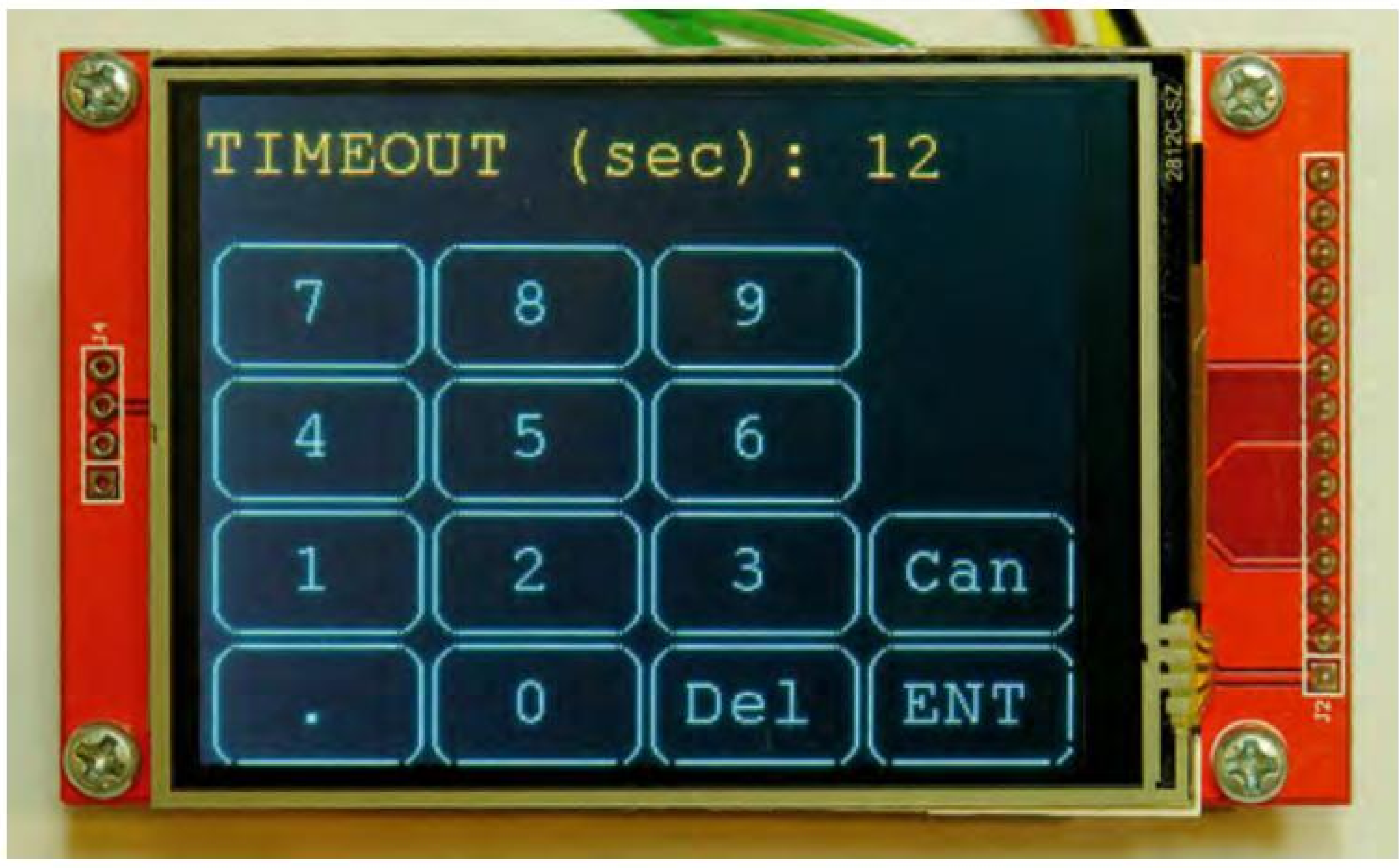
The FINISHED button will save the options and return to the previous screen. All options are saved in non-volatile memory, so they will be retained even if the power is removed.

Building the LCD Backpack

The first step in construction is building the *Micromite LCD BackPack* and testing it works correctly. This was described in last month's *EPE*, so we won't go into too much detail here. Besides, with the silk screening on the PCB, it's obvious where the parts go and it should take less than half an hour to build.

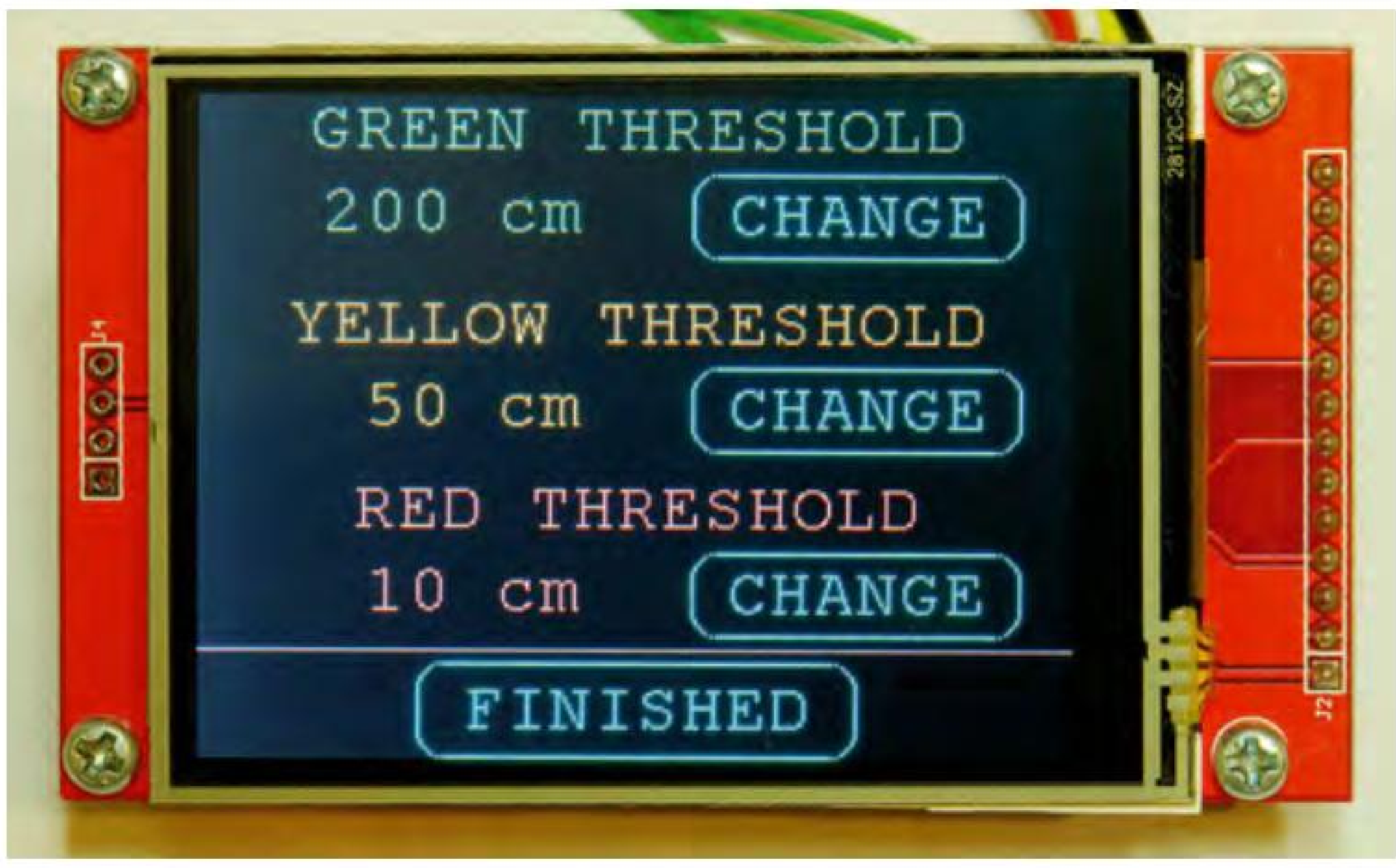
Loading the firmware and the BASIC program is a three-step process. First, the blank PIC32 microcontroller must be programmed with the Micromite firmware, which includes the BASIC interpreter (MMBasic). That done, the interpreter needs to be configured to suit the LCD panel. And finally, the BASIC program that drives the ultrasonic sensor and the display needs to be loaded. You do have a few choices when it comes to this process:

Option 1: the first option is to download the file **`ParkingAssistFull.hex`** from the *EPE* website and program the PIC32 yourself. This file has the Micromite firmware, the settings for the LCD panel and the BASIC program all combined into one 'package'. It must



TIMEOUT (sec): 12

This is a typical virtual keypad which allows the user to enter a new number. It includes the ability to delete the previously entered digit (the DEL key) or cancel the entry and return to the menu (the CAN key). Pressing ENT will store the number and return to the previous menu.



GREEN THRESHOLD
200 cm
YELLOW THRESHOLD
50 cm
RED THRESHOLD
10 cm

The thresholds for bringing up different background colours can be changed using this menu. The Finished button saves the options and returns to the previous screen. All options are saved in non-volatile memory so that they will be retained even if the power is removed.

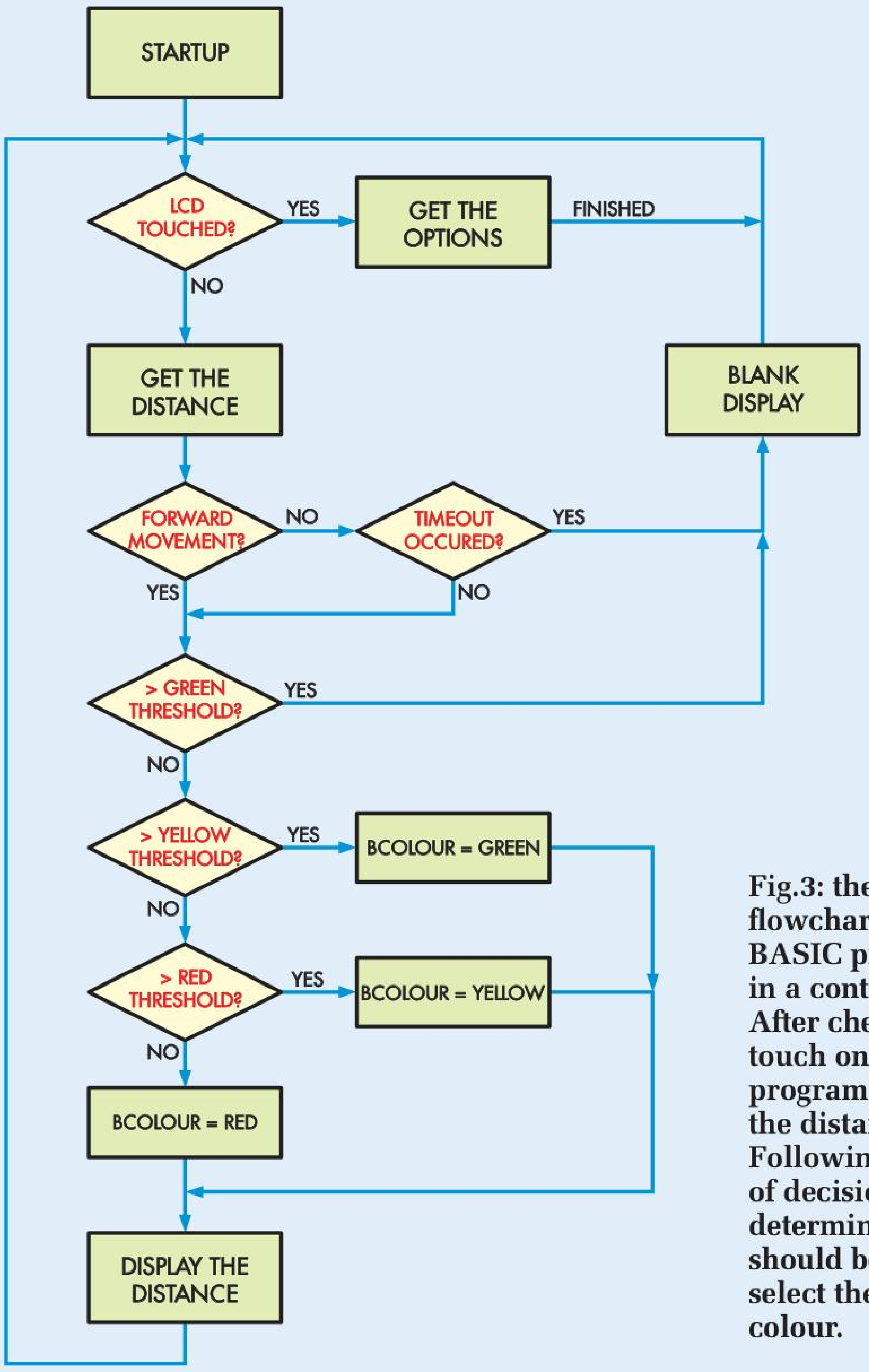


Fig.3: the software flowchart diagram. The BASIC program runs in a continuous loop. After checking for a touch on the screen the program then measures the distance to the car. Following this, a series of decisions are made to determine if the display should be blanked or to select the background colour.

be programmed into the PIC32 microcontroller using a programmer such as the PICkit 3.

Using this firmware is quite convenient because this single operation combines all three steps and sets up the chip so that it's ready to do the job.

Option 2: the second (and easiest) option is to purchase the PIC32 microcontroller pre-programmed with the combined firmware file from the SILICON CHIP Online Shop. Then, all you need to do is plug the chip into its socket and you are ready to go.

Option 3: the third option is to go through all three steps individually. Step 1 is to download the file **`Micromite_V5.1.hex`** from the *EPE* website and program it into the PIC32 microcontroller using a PICkit 3. Step 2 is to connect a USB-to-serial converter to the Micromite's console and configure the chip to work with the LCD and touch. And finally, step 3 involves loading the BASIC program **`ParkingAssist.bas`** (again available from the *EPE* website). This can be loaded using either the XMODEM protocol or using the AUTOSAVE command.

The above process was described in detail in last month's article on the *Micromite LCD Backpack* and isn't hard to do. When you have run through all three steps, the result will be exactly the same as if you had loaded the combined firmware containing the interpreter, the settings and the BASIC program (or if you purchased a preprogrammed chip).

The only issue that you need to be aware of is that the touch calibration in the combined firmware was done with a reasonably standard LCD panel, but yours might require re-calibration if it is significantly different from the 'standard' that we used. If you discover that the touch calibration is inaccurate, this can be corrected by connecting a USB-to-serial converter to the console, halting the program with CTRL-C and re-running the calibration. The calibration procedure was also described in detail last month.

Note that if you already have a working *Micromite LCD BackPack*, then it will only be necessary to load **`ParkingAssist.bas`** into the PIC32 micro. Alternatively, you can choose to reprogram the chip with the combined software (ie, **`ParkingAssist-Full.hex`**).

Program operation

If you wish to modify the BASIC program, you need to have some idea of how it works. Fig.3 provides a high-level flow diagram of its operation.

As shown, the program runs in a continuous loop. First, it checks if the LCD is being touched and if it is, branches to a subroutine which will display the menus and the options.

The program then retrieves the distance from the ultrasonic sensor, which is averaged over five successive readings to reduce noise. It then checks for forward movement, and if there is none it checks for a timeout. This is the time that the display remains on after the vehicle has stopped moving. If the vehicle is stationary, a counter will increment every second and the program will blank the display when the counter reaches the timeout setting.

The program next checks the vehicle's distance and compares it to the green threshold. If it is greater than this threshold, it blanks the display and returns to the start of the loop for another 'go around'. If the distance is less than the green threshold, the program checks the other thresholds to determine the colour to be used, ie, green, yellow or red.

Finally, the program displays the distance in centimetres with the specified coloured background. It then loops around to get another distance reading and repeats the process.

If you are going to modify the program there is one feature that you need to be aware of. In the main program loop, the watchdog timer is set to one second. This timer is used to automatically restart the program if an error occurs.

In operation, the timer must be constantly reset to one second to prevent

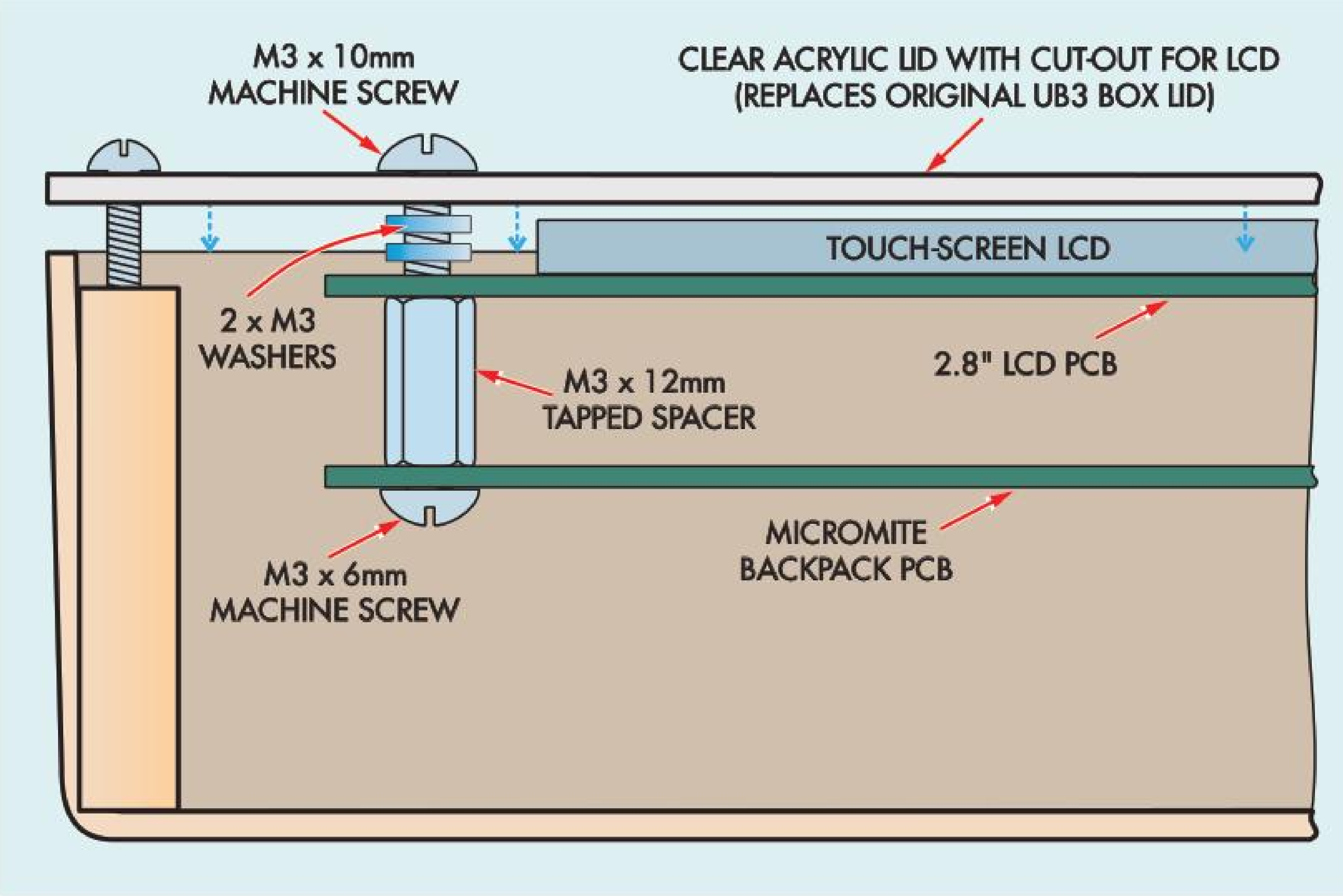
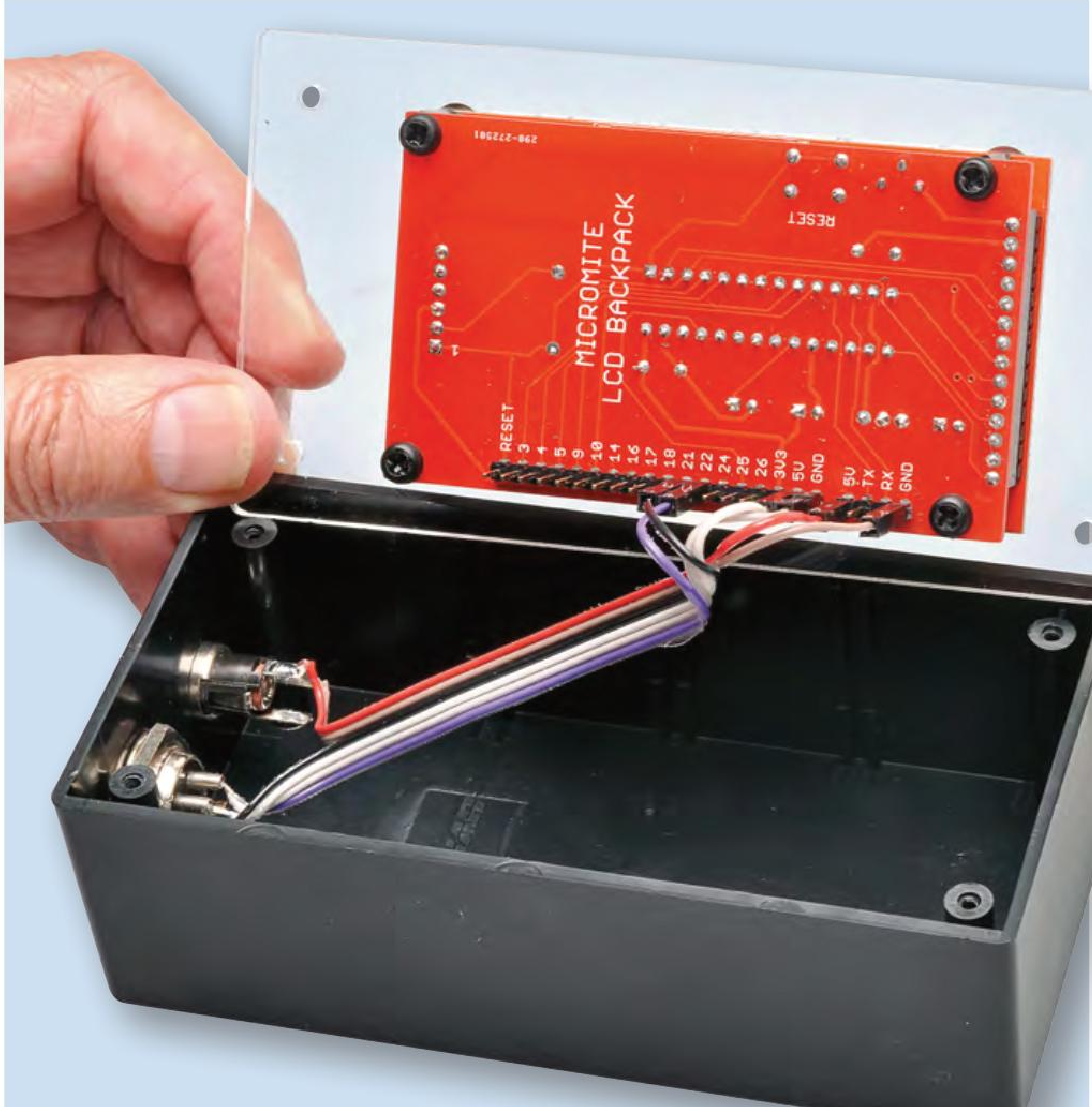


Fig.4: here's how to attach the LCD and *Micromite BackPack* PCB to the clear acrylic lid. The LCD goes through a cut-out in the lid and sits flush with its top surface.



This view shows the LCD/BackPack PCB assembly just before it is lowered into the case.

a restart under normal operation. This means that you must make sure that the program can execute the loop in less than one second to avoid an automatic restart of the Micromite.

The watchdog timer is also used when the program detects a touch on the screen and branches to the menus where the options are set. In this case, the timeout is set to 10 minutes every time a button is touched. This was included in the program so that the Micromite will automatically restart and return to normal operation after 10 minutes of inactivity within any menu – handy if you have been called away while fiddling with the settings and forget to return.

Building it

The first job in the assembly is to build and calibrate the *Micromite LCD BackPack*, as detailed in last month's *EPE*. It's then just a matter of mounting the *LCD BackPack* assembly and the ultrasonic sensor assembly in separate enclosures and connecting them together.

As shown in the photos, the *Micromite LCD Backpack* is mounted inside a UB3 ABS box, while the ultrasonic sensor goes in a smaller UB5 box. A 4-core cable joins the two units and allows the sensor to be mounted at bumper bar height, while the *Micromite LCD BackPack* can be mounted above it at eye height.

In each case, the lid supplied with the box is discarded and replaced with a laser-cut clear acrylic panel (available from the SILICON CHIP Online Shop; see parts list). The panel for the *BackPack* assembly comes with all the mounting holes plus a precision cut-out for the touch-screen LCD, while the panel (or lid) for the UB5 box comes with corner mounting holes plus neat circular cut-outs for the two ultrasonic transducers.

Fig.4 shows how the *LCD BackPack* assembly is mounted. First, the touch-screen LCD is attached to the acrylic lid at each corner using an M3 × 10mm machine screw, two stacked M3 washers and an M3 x 12mm tapped spacer. This arrangement ensures that the LCD sits flush with the clear acrylic lid.

Note that the LCD itself is offset to the left on its PCB, so be sure to fit the module the right way around, so that the viewing area is centred horizontally on the acrylic panel. Once it's in place, the *Micromite BackPack* PCB is then plugged into CON3 on the LCD board and secured in place using M3 × 6mm machine screws.

The next step is to drill holes in the lefthand side of the case to accept a panel-mount DC power socket and a 4-pin microphone socket (used for the sensor connection). These holes can be centred vertically on the panel, with each hole about 20mm in from its adjacent outside edge.

Drill small pilot holes and then carefully enlarge each hole to size using a tapered reamer, so the part just fits.

That done, the DC socket is wired to a 4-pin female header (see Fig.5) with the red wire going to the centre pin terminal. The DC socket is then secured to the case, after which the microphone socket can be fitted and wired to an 8-pin female header – see Fig.6.

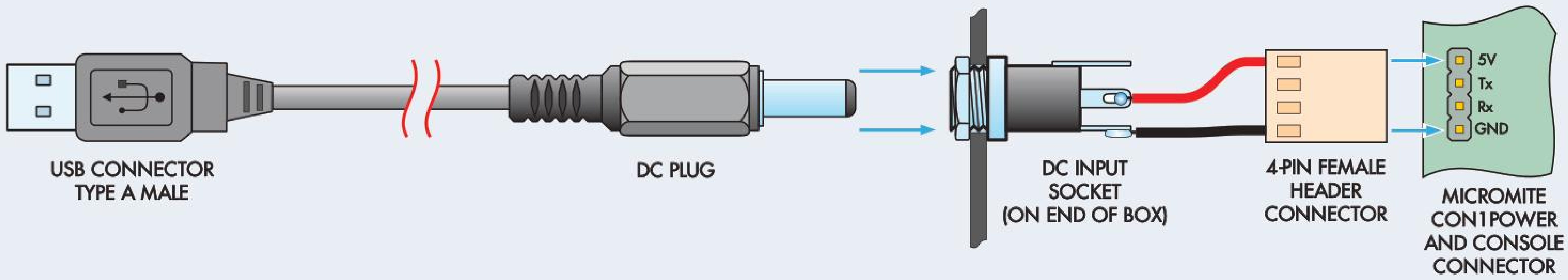

USB CONNECTOR TYPE A MALE
DC PLUG
DC INPUT SOCKET (ON END OF BOX)
4-PIN FEMALE HEADER CONNECTOR
5V
Tx
Rx
GND
MICROMITE CON1 POWER AND CONSOLE CONNECTOR

Fig.5: the *Garage Parking Assistant* is powered from a standard USB plugpack charger. To make a suitable power cable, cut off one end of a USB cable (retaining the type A male connector on the other end) and solder the red wire to the centre terminal pin of a DC plug and the black wire to the outside pin. The matching DC socket is mounted on the side of the UB3 box and is connected to a 4-pin female header, which then plugs into CON1 on the Micromite PCB.

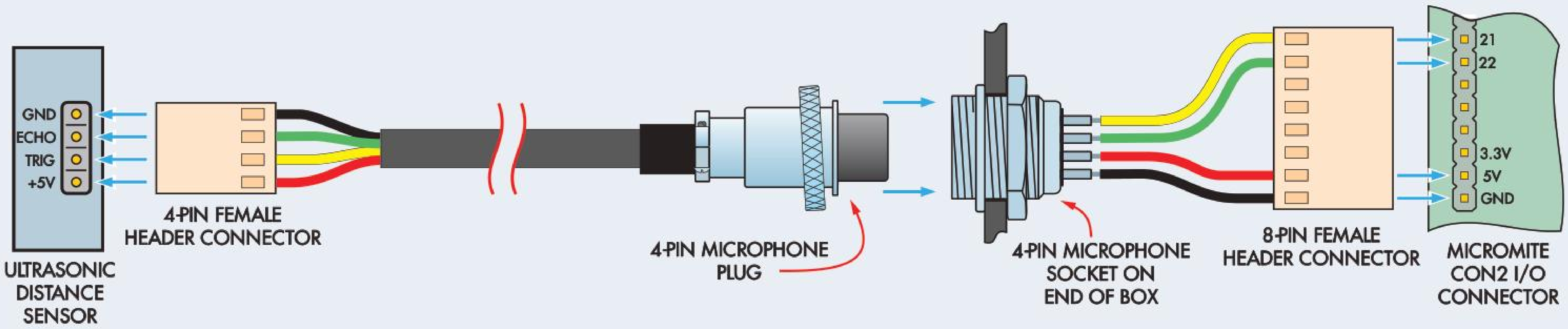

GND
ECHO
TRIG
+5V
ULTRASONIC DISTANCE SENSOR
4-PIN FEMALE HEADER CONNECTOR
4-PIN MICROPHONE PLUG
4-PIN MICROPHONE SOCKET ON END OF BOX
8-PIN FEMALE HEADER CONNECTOR
21
22
3.3V
5V
GND
MICROMITE CON2 I/O CONNECTOR

Fig.6: a cable with a 4-pin female header at one end and a 4-pin microphone plug at the other end connects the ultrasonic sensor to the display unit via a matching 4-pin socket. The microphone socket in turn is wired to an 8-pin female header which then connects to CON2 on the Micromite PCB. Note that the female headers shown in Figs.5 and 6 are not polarised, so make sure that they are oriented correctly when plugging them in.

The main unit can now be completed by plugging the headers into CON1 and CON2 on the *BackPack* PCB, then lowering the PCB assembly into the case and securing it at the corners using the supplied self-tapping screws.

Be careful when plugging in the two headers, as the connectors are not polarised. Basically, it's just a matter of making sure that ground (GND) from the DC socket (black wire) goes to GND on CON1 and that GND on the microphone socket goes to GND on CON2.

Note that CON2 on the *BackPack* PCB has 18 pins; the 8-pin female header must be plugged in at the end that has the GND pin.

Fitting the sensor PCB

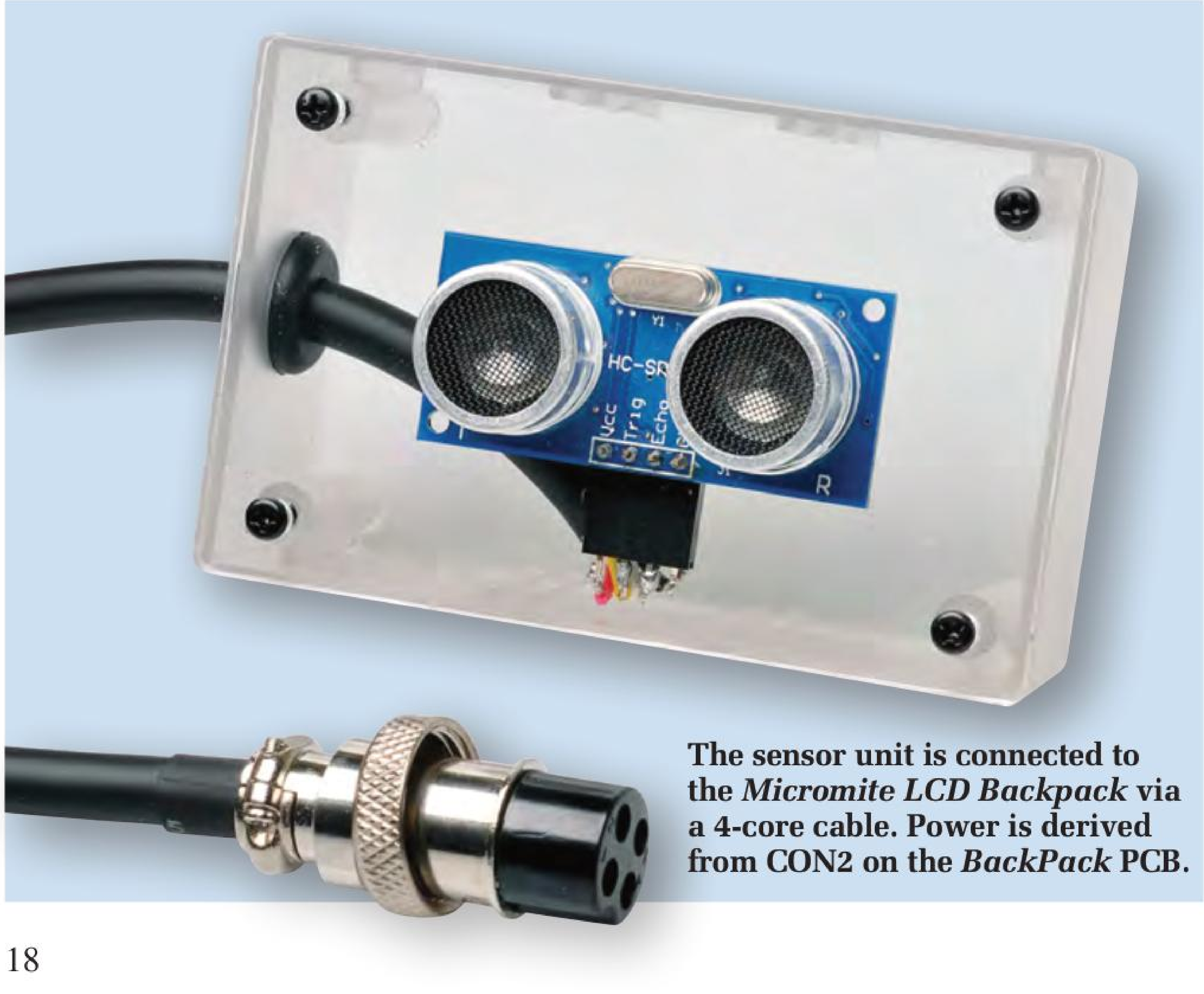
The ultrasonic sensor unit comes preassembled. It's just a matter of pushing the two sensors through their front panel holes as far as they will go to secure the unit in position. The sensors are a firm fit in the holes and that will usually be enough to hold the assembly in place.

Alternatively, a couple of small dabs of neutral-cure silicone can be used on the inside to ensure that the sensor unit can't be pushed back into the case.

The next step is to drill a 9.5mm hole through one side of the case (or through the top) and fit a rubber grommet. A 4-way cable (used to connect the sensor to the *Micromite BackPack* PCB) is then pushed through this grommet and wired to a 4-way female header, as shown in Fig.6.

Either 6mm-diameter 4-core audio cable (with the shield braid cut short) or 4-wire telephone cable can be used here. The audio cable is a tight fit into the grommet, so it won't be necessary to secure it with a cable clamp. Conversely, some sort of clamping arrangement will probably be required if telephone cable is used.

The other end of this 4-way cable is connected to a 4-pin microphone plug. Make sure that the wires go to the correct pins on this plug, so that they mate with the correct wires on the socket when the two are connected together. If you are using audio cable, the shield braid can either be cut short or connected to the plug's metal shell.


HC-SR
Vcc
Trig
Echo
Y1
T
R

The sensor unit is connected to the *Micromite LCD Backpack* via a 4-core cable. Power is derived from CON2 on the *BackPack* PCB.

Firmware updates

For firmware updates for the Micromite and the *Garage Parking Assistant*, please check the author's website at: **geoffg.net/micromite.html**

Note that the ultrasonic sensor assembly derives its power (5V) via this cable from CON2 on the *Micromite BackPack PCB*.

Power supply

5V USB plugpack chargers are cheap and the *Garage Parking Assistant* works perfectly with one of these. Be sure to select one with a generous current rating (500mA or more), as the unit can draw up to 250mA.

Fig.5 shows the details for the USB supply cable for one of these supplies. It's just a matter of cutting off one end of a USB cable (retaining the male type A connector at the other end) and soldering the red and black wires to the DC plug (red wire to the centre-pin terminal).

The other two wires in the USB cable (generally green and white) can be cut short, as they are not needed.

Another option is to use a 5V DC plugpack with a captive lead fitted with a DC plug. If the plug is the incorrect size, cut it off and fit one that does match the socket.

Loading BASIC

If you are going to load the BASIC program yourself or edit it later, you also need to make up a cable with a USB-to-serial converter, as described last month. Then, after you have the program running, you can remove the converter and use the power cable instead.

This is because the program is designed to start running automatically whenever power is applied and after the program has been run once, you don't need to use the console again.

Mounting it in place

Having made the connections, the next step is to mount the two units in place. The LCD unit should be mounted on the garage wall at eye height, while the sensor should be mounted at bumper bar height.

Don't forget that you can easily adjust the green, yellow and red threshold values if necessary. Depending on how close you want to park to the wall, the default values should be fine in most cases. However, some people might want to increase the red threshold to (say) 15cm or even 20cm.

As stated earlier, all you have to do is touch the screen to bring up the main options menu and then touch the CHANGE button for the colour thresholds to bring up the relevant options menu. You then hit the CHANGE button for the threshold you want to change, enter in the new number on the virtual keypad, touch ENT and then FINISHED, and that's it!

Parts List

Micromite LCD BackPack Unit

1 PCB available from the *EPE PCB Service*, coded 07102122, 86 × 50mm (for 2.8-inch LCD)
1 ILI9341-based LCD, 320 × 240 pixels, 2.8-inch diagonal
1 UB3 ABS box, 130 × 67 × 43mm
1 pre-drilled clear acrylic lid to suit UB3 box
1 4-pin tactile switch, through-hole hole
1 100Ω vertical-mount side adjust trimpot
1 28-pin DIL low-profile IC socket
1 4-pin 0.1-inch male header (CON1)
1 18-pin 0.1-inch male header (CON2)
1 14-pin 0.1-inch female header socket (CON3)
1 6-pin 0.1-inch right-angle male header (CON4)
1 4-pin 0.1-inch female header
1 8-pin 0.1-inch female header
1 2.1mm or 2.5mm panel-mount DC socket
1 4-pin panel-mount microphone male socket
4 M3 × 12mm tapped spacers
4 M3 × 10mm machine screws
4 M3 × 6mm machine screws
8 M3 flat washers

Semiconductors

1 PIC32MX170F256B-50I/SP microcontroller programmed with ParkingAssistFull.hex (IC1) – see text. Note: a PIC32-MX170F256B-I/SP can also be used but will be limited to 40MHz)
1 Microchip MCP1700-3302E/TO voltage regulator (REG1)

Capacitors

1 47μF 16V tantalum or SMD ceramic (3216/1206)
2 10μF 16V tantalum or SMD ceramic (3216/1206)
2 100nF monolithic ceramic

Resistors (0.25W 5%)

1 10kΩ

Sensor unit

1 ultrasonic distance sensor, HC-SR04, SRF05, SRF06, Parallax PING or DYP-ME007
1 UB5 ABS box, 82 × 54 × 30mm
1 pre-drilled clear acrylic lid to suit UB5 box
1 9.5mm rubber grommet to suit 6mm-dia. cable

Cable parts

1 USB cable with a male type A connector (length to suit)
1 2.1mm or 2.5mm DC plug to suit DC socket
1 4-pin female line microphone connector
1 4-pin 0.1-inch female header
1 length 4-core audio cable
1 200mm length of rainbow cable

Where To Buy Parts

A complete kit for the *Micromite LCD BackPack* is available from the Silicon Chip Online Shop. The clear lid with cut-out, to suit a UB3 Jiffy box, is available separately. You can also buy the ultrasonic distance sensor with a custom-cut UB5 jiffy box lid. See the Online Shop for details: www.siliconchip.com.au/Shop/

The Micromite BackPack PCB and programmed microcontroller can also be purchased separately.

Note that the kit does not include the boxes, mounting hardware, plug-pack power supply, rubber grommet off-board headers and connectors or cable parts.

Reproduced by arrangement
with SILICON CHIP
magazine 2017.
www.siliconchip.com.au

Design by JOHN CLARKE

The alarm unit sits inside the safe and sounds an alarm if the safe door is opened unless the correct code is entered before the entry delay period expires.

ELECTRONIC SAFE ES20
Sandleford
Unauthorised Opening
Hotel Safe Alarm
Door Open/ Alarm Pending
Enter Code
1
2

Hotel Safe Alarm

Are you a frequent tourist? Then you will be familiar with the small safes in every room in most hotels and in the cabins on cruise ships. This *Hotel Safe Alarm* tells you if the safe has been opened in your absence and will also give the offender a very bad feeling that he or she has been detected. Their natural reaction will be to close the safe and abscond immediately.

ANYONE WHO regularly travels on cruise ships or stays in hotels will be familiar with the ubiquitous room safe, which is usually inside the wardrobe. The safe has a 4-digit LED display and a numeric keyboard to let you enter a 4-digit code before closing it and again when you wish to open it.

They are very handy, but it would be naive to think that these safes offer a high degree of safety for your valuables. After all, if you forget the code or the safe malfunctions, it is a straightforward exercise for the hotel staff to open them. That means that there could be people lurking about in hotel or ship corridors that don't have your best interests at heart. And since they will attempt their nefarious activity while you are absent, how can you discourage them? The answer is to use our *Hotel Safe Alarm*.

Of course, you could also use this alarm in a safe at home, or in a filing cabinet or desk drawer that you want to monitor. And you could use it to monitor a tool cupboard, pantry (against hungry teenagers marauding at night?) or whatever.

The *Hotel Safe Alarm* is a small plastic box with two LEDs (red and green) and two pushbutton switches. A light dependent resistor (LDR) detects when the safe has been opened and it will react to room lighting or a torch. An LED starts blinking immediately and if you don't enter a code via the two buttons within 15 seconds, the inbuilt piezo transducer will start screaming at you (or the offender).

The duration of the alarm is 60 seconds as the default setting, but this can be set to between 10 seconds and 120 seconds, in 10-second increments.

If your safe has been opened in your absence, the alarm will indicate that by alternately flashing the red and green LEDs. To clear this alarm condition, you just feed in the entry code by pushing the two buttons in the normal way.

We'll describe how you enter the code and various time settings later in this article.

Features

- **Powered by a lithium button cell**
- **Armed indication (green LED2)**
- **Entry indicator (red LED1)**
- **Piezo alarm**
- **Low current drain**
- **Adjustable entry delay period**
- **Adjustable alarm period**

Circuit details

The circuit is very simple; just an 8-pin PIC microcontroller, two LEDs, two pushbuttons and a few other components – see Fig.1. It is powered by a 3V lithium button cell and is switched on via jumper link, JP1. This can be

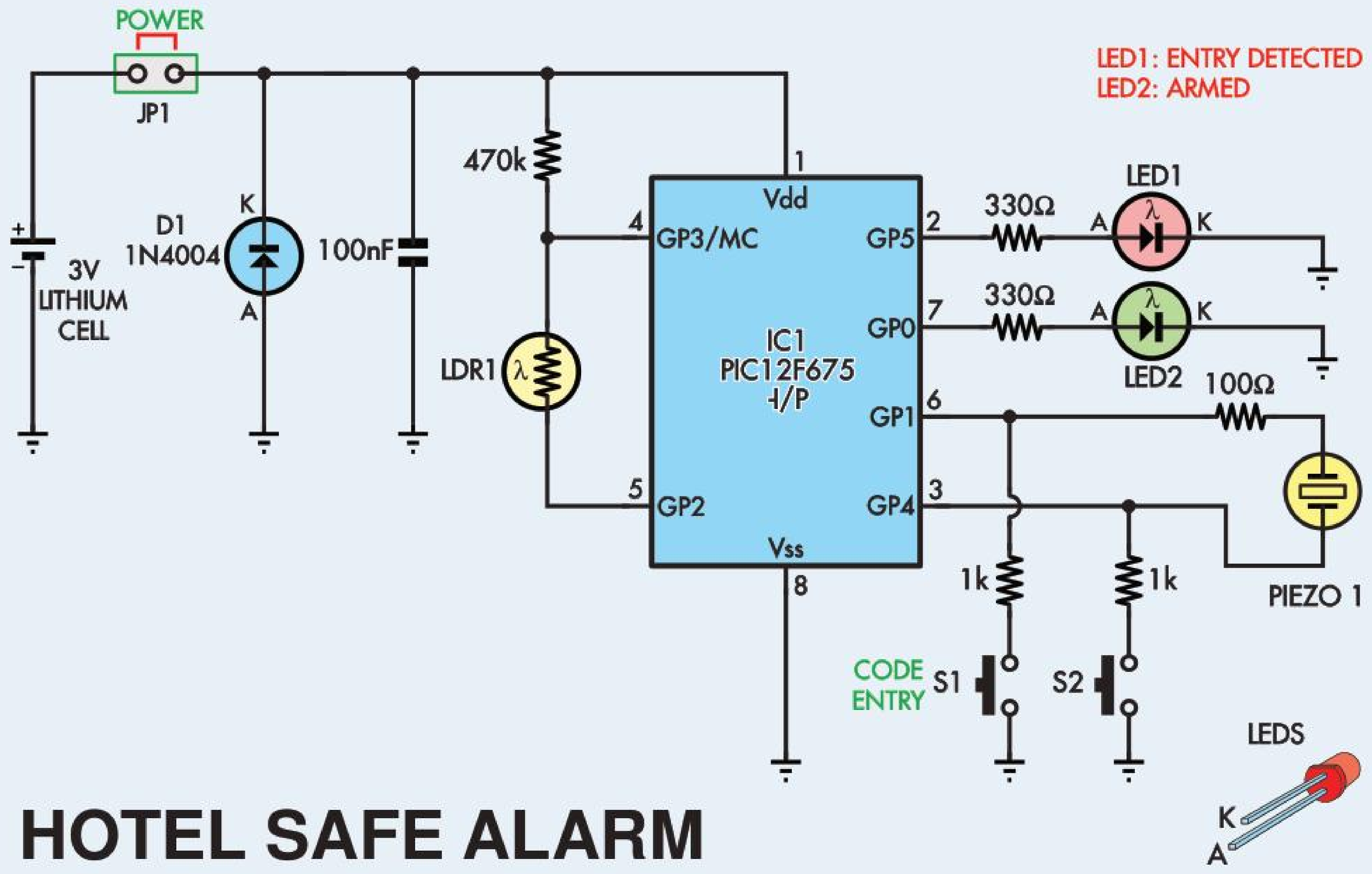


Fig.1: the circuit is based on PIC microcontroller IC1, light-dependent resistor LDR1, a couple of LEDs and a piezo transducer. If the safe is opened, LDR1's resistance goes low and pulls pin 4 of IC1 low to start the alarm entry timer. The correct code then has to be entered within 15 seconds via pushbutton switches S1 and S2 to stop the alarm from sounding.

Specifications

Power	3V at typically 2.5µA
Alarm current	0.5mA
Alarm entry delay	adjustable from 1-60s in 1s steps; initial value is 15s
Alarm period	10s to 120s, in10s steps. Default value is 60s
Alarm disable code	any code sequence from one to eight switch presses
Alarm signal	280ms bursts of 4-6kHz with 220ms gap between bursts

removed when you are not using the alarm, to save the battery.

IC1 is a PIC12F675-I/P microcontroller and it is programmed with a tricky bit of software that lets you enter the necessary settings with only two pushbuttons. Normally, IC1 is in sleep mode and its watch-dog timer wakes it about every 2.3 seconds and it briefly checks the ambient light via the LDR, as follows.

Normally, IC1's GP2 output at pin 5 is set high (at 3V), so there is no current flow through the 470kΩ resistor and the LDR. This is done to minimise current drawn from the 3V cell. When IC1 wakes up, it sets GP2 low (0V) and then monitors the voltage at input GP3 (pin 4).

In darkness, the LDR resistance is high (well above 1MΩ) so the voltage at pin 4 will be high, at close to 3V, so IC1 (yawn) goes to sleep again. If it wakes and the LDR is exposed to ambient light, its resistance will be much lower, perhaps as little as 10kΩ in bright light. So the voltage at pin 4 will be low and IC1 starts to get excited. Well, perhaps not, but it starts flashing green LED2 to indicate that the alarm is about to start sounding.

Provided the valid code is now entered with the two pushbuttons during the 15-second delay period, the alarm is disabled. If no code or an invalid code is entered, the piezo transducer sounds, as pins 6 and 3 (GP1 and GP4) alternately go high and low, to deliver bursts of 4kHz signal. In the confined space of a hotel safe and at close quarters, this can be quite loud.

Certainly, there is no mistaking that the miscreant has been 'pinged'. As already mentioned, the alarm will sound for the default period of 60 seconds (unless programmed to do otherwise).

The scope screen grabs of Fig.2 and Fig.3 show the complementary drive signals applied to the piezo transducer. In Fig.2, the two signals are at 3.99kHz and have an amplitude very close to 3V peak-to-peak, not allowing for the overshoot spikes. Therefore, the total signal applied to the transducer will be very close to 6V peak-to-peak or about 3V RMS, as shown in the red trace of Fig,2.

Fig.3 shows the same complementary drive signals but at a much slower sweep speed of 100ms/div. This shows the signal bursts which are about 280ms long and separated by gaps of approximately 220ms.

Parts List

1 double-sided PCB available from the *EPE PCB Service*, coded 03106161, 61 × 47mm
1 front-panel label, 74 × 47mm
1 UB5 translucent clear or blue case, 83 × 54 × 31mm
1 20mm button cell holder
1 CR2032 lithium cell (3V)
2 SPST PCB mount snap-action switches (S1,S2)
1 30mm-diameter piezo transducer
1 10kΩ light-dependent resistor (LDR1)
1 DIL8 IC socket
2 M3 tapped 12mm spacers
2 M3 tapped 6mm spacers
6 M3 × 6mm machine screws
2 M3 × 6mm machine screws
2 M3 × 6mm countersink screws
1 2-way pin header (2.54mm pin spacing) (JP1)
1 jumper shunt
2 PC stakes
1 25mm length of 2mm-diameter heatshrink tubing

Semiconductors
1 PIC12F675-I/P programmed with 0310616A.hex (IC1)
1 1N4004 diode (D1)
1 3mm red high brightness LED (LED1)
1 3mm green high brightness LED (LED2)

Capacitor
1 100nF 63V or 100V MKT polyester or ceramic

Resistors (0.25W, 1%)
1 470kΩ
2 1kΩ
2 330Ω
1 100Ω

Reproduced by arrangement with SILICON CHIP magazine 2017. www.siliconchip.com.au

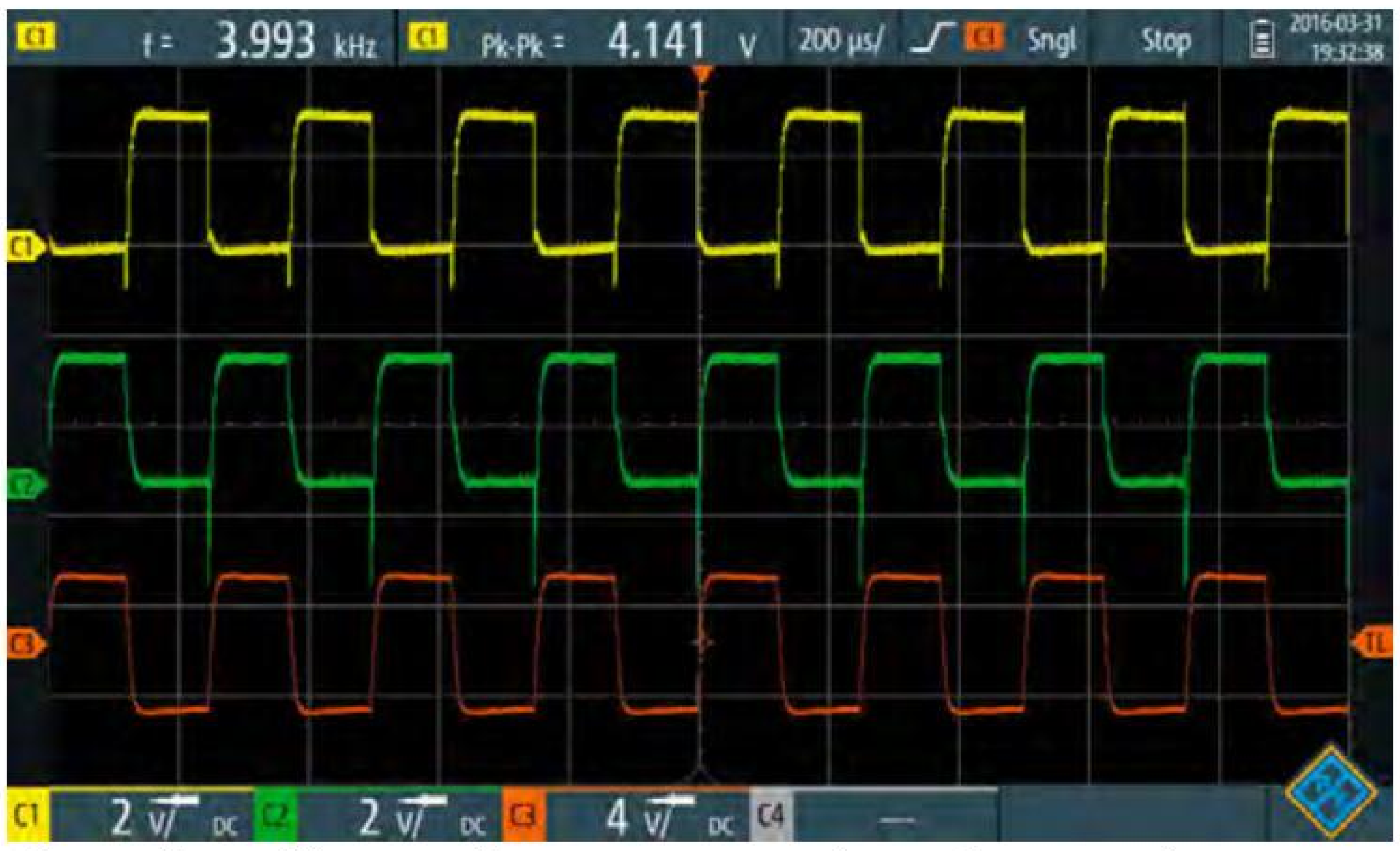


Fig.2: the yellow and green traces show the complementary drive signals applied to the piezo transducer. The two signals are at 3.99kHz and have an amplitude that's close to 3V peak-to-peak, not allowing for the overshoot spikes. The total signal applied to the transducer is shown in the red trace and is 6V peak-to-peak

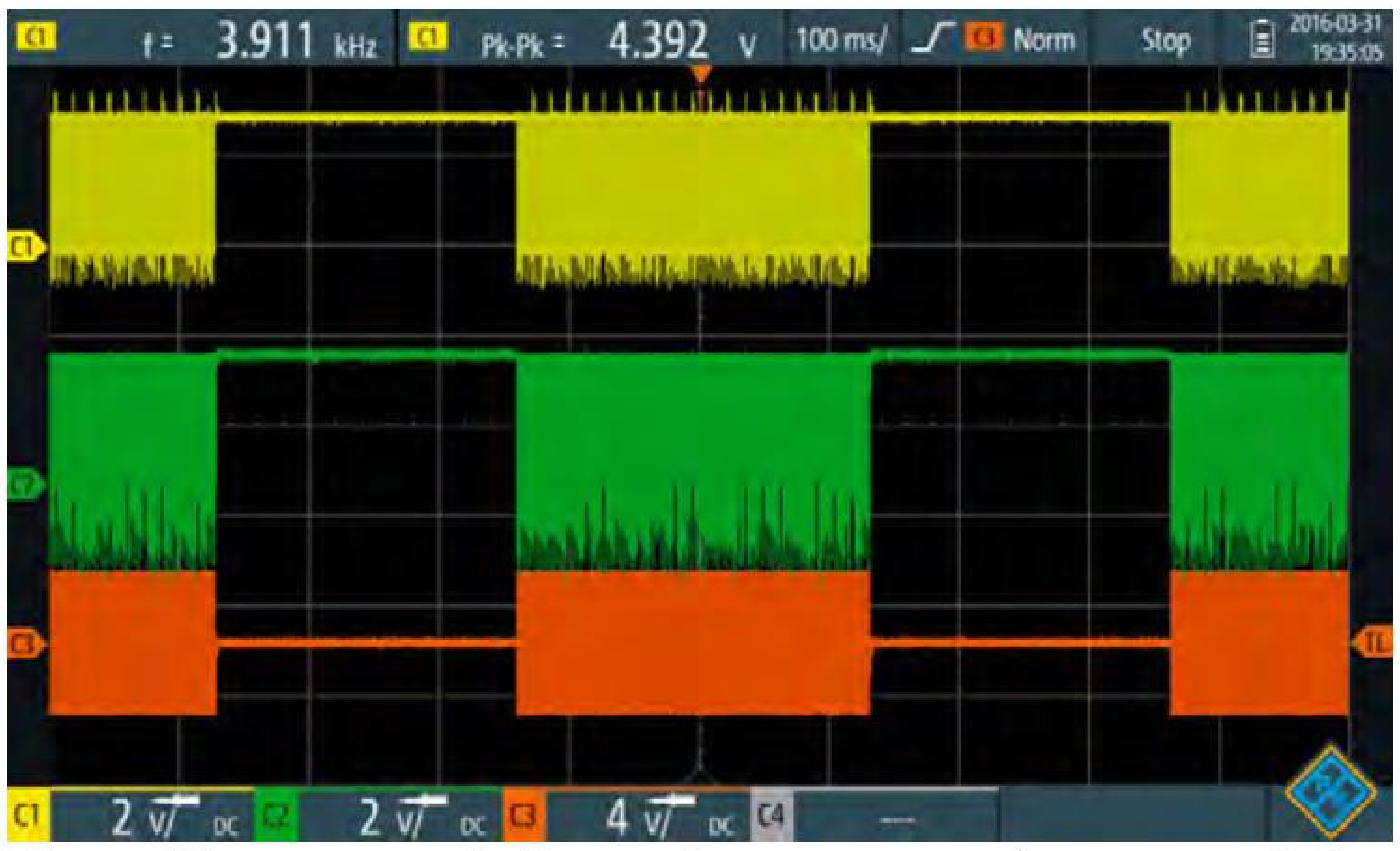


Fig.3: this scope grab shows the same complementary drive signals but at a much slower sweep speed of 100ms/div. The signal bursts are about 280ms long and are separated by gaps of approximately 220ms. The red trace shows the total signal applied to the transducer and is 6V peak-to-peak.

If the safe door is hastily closed again, the alarm will continue to sound for the remainder of the 60-second period and then go back to sleep. When the safe door is re-opened, the red and green LEDs will alternately flash for 15 seconds, unless you enter the valid code. If not, the piezo alarm will begin beeping again. And continues the cycle. . .

So, as well as providing some deterrent by sounding the alarm if a valid code is not entered, it will also tell you that the safe has been opened in your absence, even if it has been closed after being detected.

Button detection

As well as providing the drive signal for the piezo transducer, pins 6 and 3 (GP1 and GP4) monitor the state of the two momentary contact pushbutton switches, S1 and S2. To do this, GP1 and GP4 are set as inputs, which are normally high but they can be pulled low via the 1kΩ resistors in series with the switches. So if S1 is closed, pin 6 (GP1) will be pulled low.

The 1kΩ resistors are included so that pressing the switches when the alarm is sounding will not short out the alarm signal to the piezo transducer.

Battery power

As already noted, the circuit is powered by a 3V button cell, via link JP1. When IC1 is in sleep mode, the current is quite low, at about 2.5µA.

The current drain when the piezo alarm is sounding is 0.5mA. And while LED2 is flashing, the current is 1.5mA (for a cell voltage of 3V).

Diode D1 is included as a safety measure to prevent damage to IC1 should the cell be connected incorrectly somehow. If the polarity is wrong, D1 will shunt the reverse current.

Reverse cell polarity could happen if the cell holder is installed the wrong way round. Alternatively, if the cell holder is installed correctly, then the diode protects the circuit if the cell is installed incorrectly. Note, for the particular cell holder we used, there is no way the cell can be inserted incorrectly and make a connection to the circuit.

IC1's power supply is bypassed with a 100nF capacitor and IC1 runs using its internal 4MHz oscillator, which is shut down during sleep mode.

LED2's brightness provides an indication of the cell voltage. At 3V supply, LED2 is quite bright, but will be dim when the cell voltage drops to 2V, indicating that it should be changed.

Programming trickery

Note that the GP3 input of the PIC12F675 is usually configured as the MCLR input (master clear), which allows the microcontroller to have an external power-on reset. However, for our circuit we need to use this as a general-purpose input for monitoring the LDR.

When MCLR is set up as an input, the MCLR operation is switched to an internal connection within the microcontroller so the master clear power-on reset function is not lost.

One disadvantage of using the MCLR pin as a general purpose input is that there can be a problem when programming the microcontroller. This occurs when the internal oscillator is also used to run the microcontroller (which we do). We solved this problem in the software, as discussed in the programming panel.

PCB assembly

The parts are all installed on a small double-sided PCB available from the *EPE PCB Service*, coded 03106161 (61 × 47mm). This fits inside a small (UB5) plastic case. Note that the LEDs, switches, LDR and the piezo transducer are mounted on one side of the PCB, while the remaining components are mounted on the other side.

Fig.4 shows the parts layouts for both sides of the PCB. Begin construction by installing the resistors, using a multimeter to check the value of each before inserting it into place.

Diode D1 can now be installed, taking care to orient it correctly, then fit the IC socket, orienting its pin notch as shown in Fig.4. The 100nF capacitor is soldered in next, and it can be positioned either way round. Then solder in the 2-way pin header for JP1 along with the cell holder. Make sure the plus terminal is oriented towards diode D1 on the PCB.

LED1 (red) and LED2 (green) are mounted so the top of the LED lens is 14mm above the top surface of the PCB. Make sure the longer lead of each LED (the anode) is inserted in the 'A' position on the PCB. The LDR is also mounted 14mm above the PCB surface.

Once the LEDs are in, install switches S1 and S2, again taking care to ensure that they are correctly oriented (flat side positioned as shown).

Piezo transducer mounting

The piezo transducer is mounted off the PCB, supported on M3 × 6mm

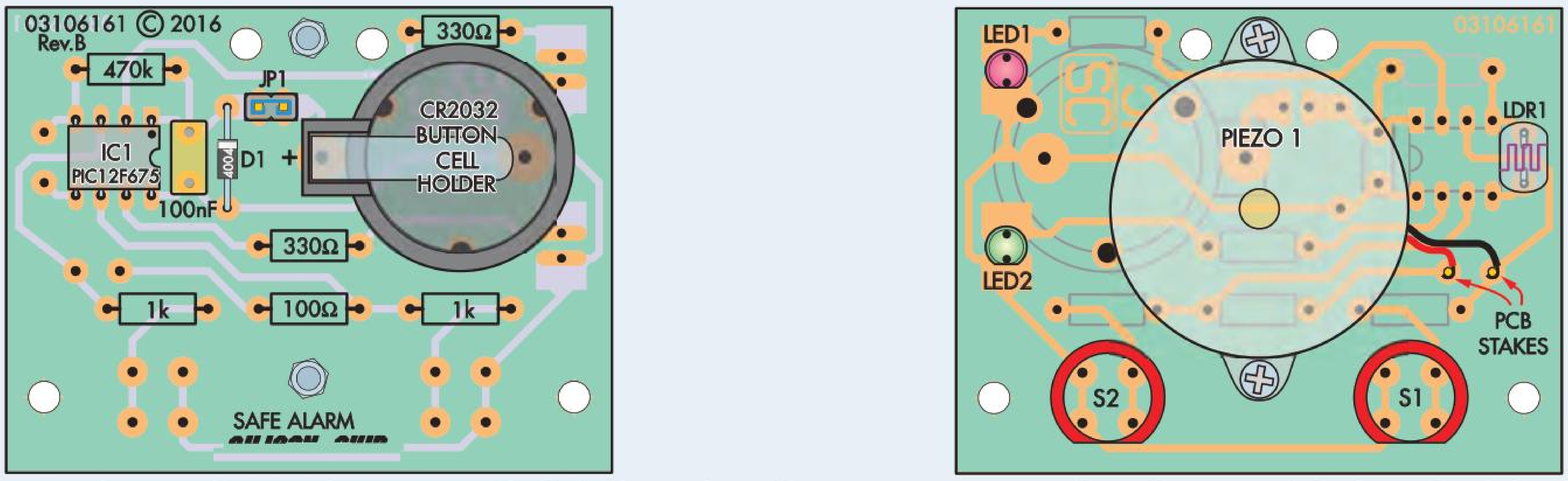
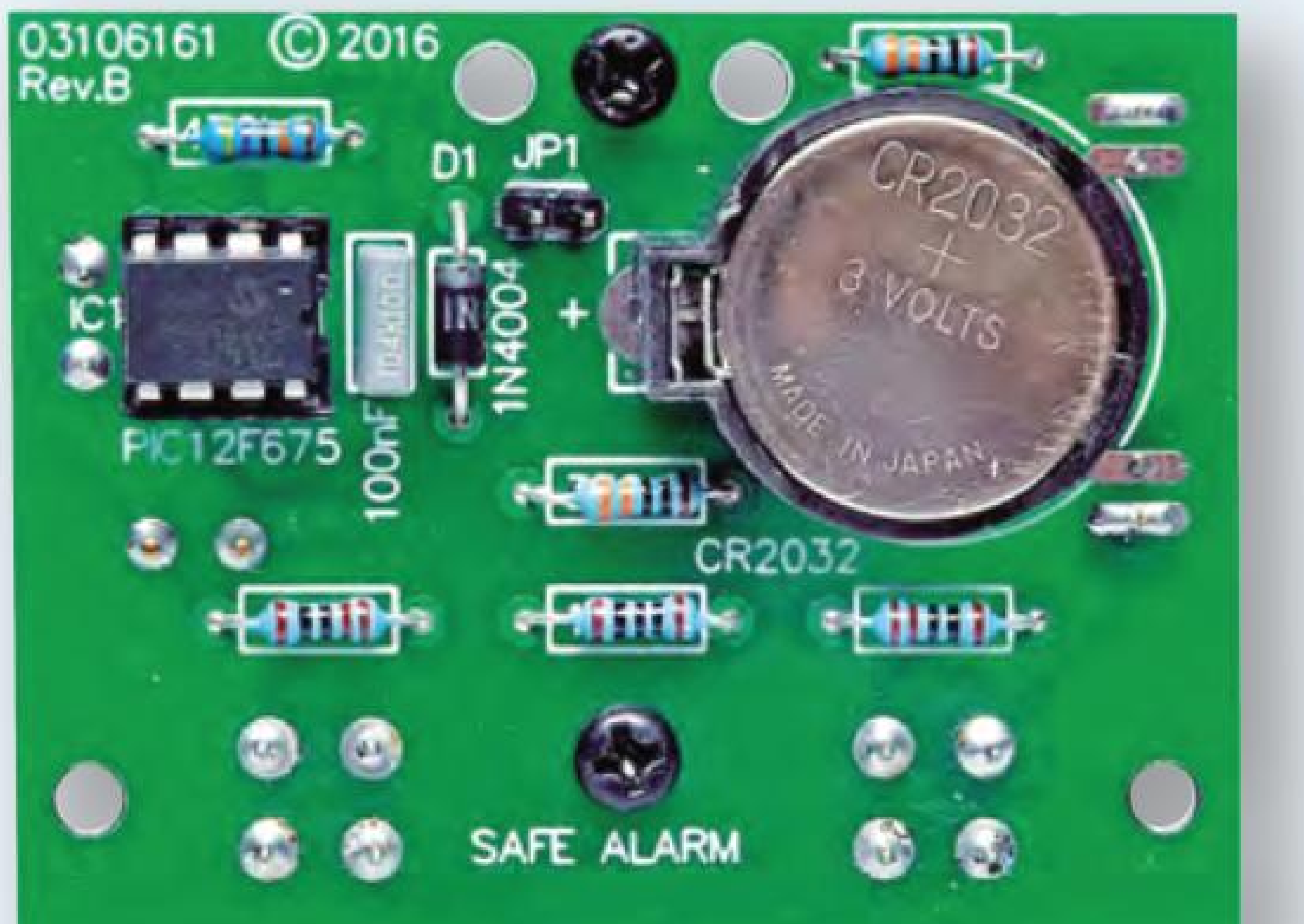
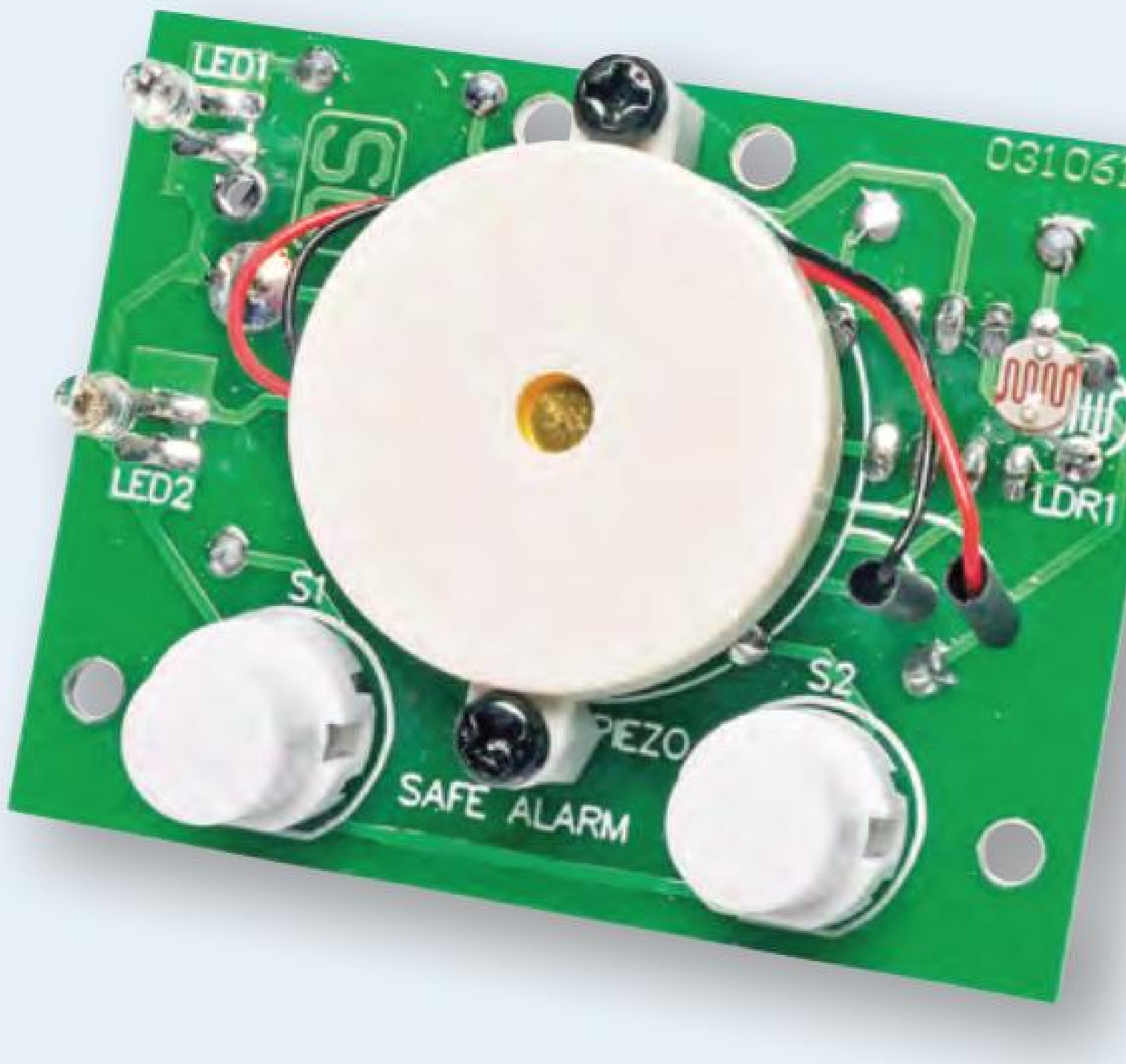


Fig.4: the PCB layout diagram on the left shows how the parts are mounted on the rear of the board, while the layout at right shows how the parts are mounted on the top side. Take care to ensure that all polarised parts are correctly oriented and note that the piezo transducer is supported on 6mm spacers and secured with M3 screws – see text.





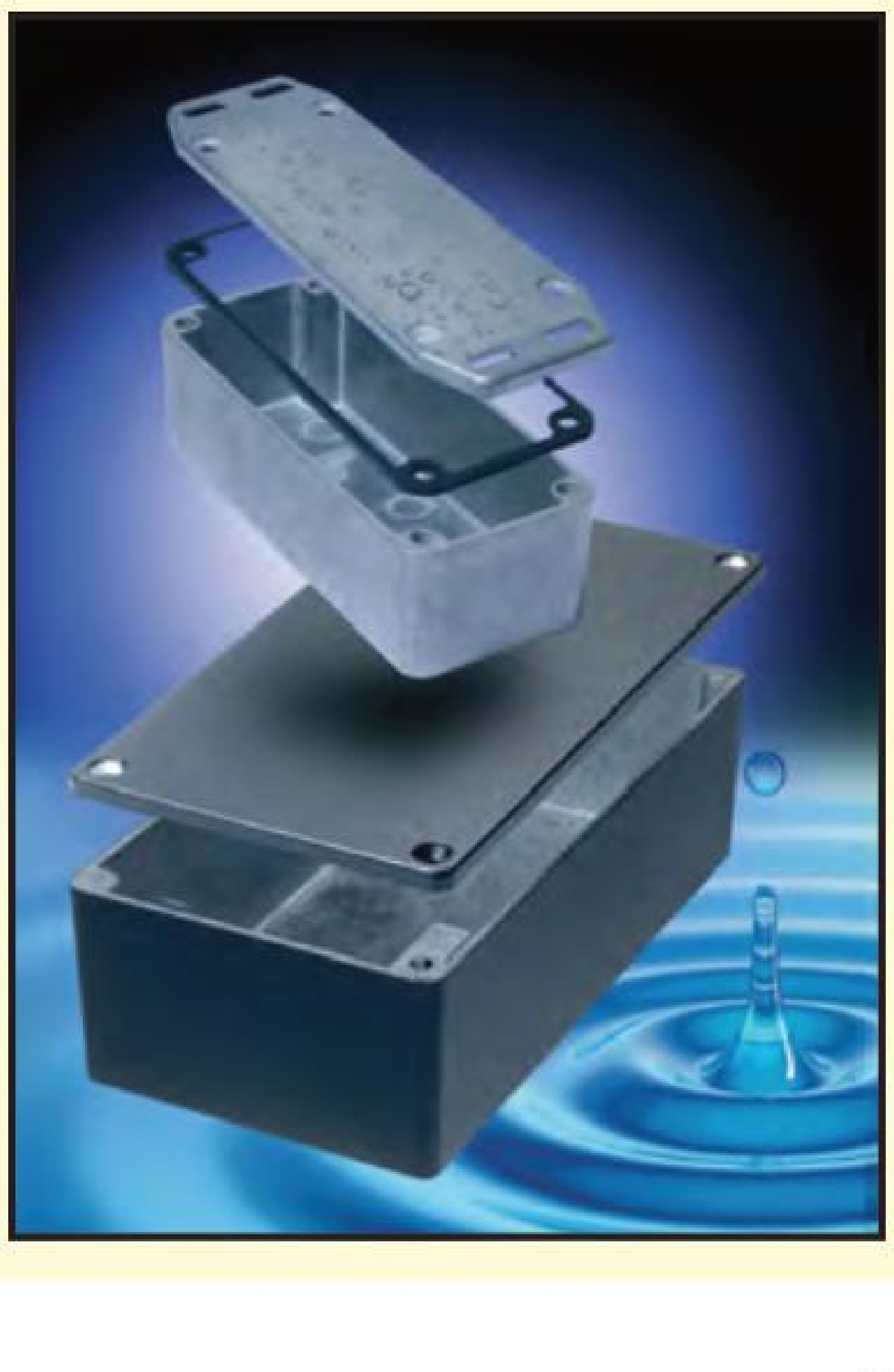
The PCB should only take about 30 minutes to assemble. Note that the LDR and the two LEDs must be mounted proud of the PCB – see text.

spacers and secured with M3 screws. The mounting holes in the lugs of the piezo transducer will need to be drilled out to 3mm for these screws. The wires are soldered to the PC stakes marked 'piezo' on the PCB. We used PC stakes for the piezo transducer wiring as this allows heatshrink tubing to be slid over the wires and PC stakes to help prevent the wires from breaking off.

While the piezo transducer may have red and black wires, the polarity of the connections is immaterial; you can connect it either way around.

If you intend to program the PIC yourself, the file **0310616A_hex** can be downloaded from the *EPE* website. Check the programming panel on the next page for details on how to do this. Or, you can purchase a pre-programmed PIC from the SILICON CHIP Online Shop.

Be sure to insert IC1 into its socket with the correct orientation and make sure you don't bend the pins under the IC. Then install the CR2032 cell in its holder and place the jumper link onto the 2-way header (JPI). If all is well, LED2 will begin to flash on and off after about three seconds, indicating that the LDR is exposed to light. The piezo transducer will then sound the alarm after the entry delay



HAMMOND
MANUFACTURING®

Die-cast enclosures
flanged & waterproof

www.hammondmfg.com/dwgfl.htm
www.hammondmfg.com/dwgw.htm

01256 812812
sales@hammondmfg.eu

Programming the PIC micro

A programmed PIC for this project can be purchased from the *Silicon Chip* online shop (**www.siliconchip.com.au**) or you may program one yourself. The software is available from the *EPE* website.

If you are programming the microcontroller yourself, you may be presented with a warning by the programmer stating that programming is not supported when both the MCLR pin is set as a general purpose input and the internal oscillator is used. Do not worry! You will be able to program the microcontroller successfully, so ignore this warning. That's because any problems associated with this configuration is already solved by a software solution. Read on if you want more details.

As mentioned, we set MCLR as a general purpose input and use the internal oscillator within IC1. This can present problems for a programmer during the process of verifying the software code after programming.

The problem is due to the fact that as soon as you program the microcontroller, it will begin executing its program. A typical program initially sets up the microcontroller with the general-purpose lines set as inputs or outputs (I/O). This conflicts with the programmer needing to use the clock and data programming I/O lines for program verification.

This problem does not happen if the MCLR pin is set as the external MCLR input because the programmer then has control over the microcontroller, stopping it from executing the programmed code.

Note also that in order to run the code, the microcontroller has to have the internal oscillator configured instead of an external crystal, RC or external clock oscillator.

The programming problem is solved in the software provided by including a 3-second delay at the start of the program. This delay is before the I/O lines are set as inputs or outputs. The I/O lines therefore remain as high-impedance inputs while the programmer verifies the internally programmed code using the clock and data programming lines.

A warning from the programmer will still be issued, but the microcontroller can be programmed successfully and correctly verified by the programmer.

Note that the PIC12F675 also needs special programming due to the fact that it has an oscillator calibration value (OSCAL) that is held within the PIC's memory. This calibration value is individually programmed into each PIC by the manufacturer and provides a value that sets the PIC to run at an accurate 4MHz rate using the internal oscillator.

This value must be read before erasure and programming so that it can be included with the rest of the code during programming. If this procedure is not done, then the oscillator could be off frequency and that will have an effect on the *Hotel Safe Alarm's* sound.

Most PIC programmers will automatically cater for this OSCAL value, but it is worth checking if your programmer correctly handles this, especially if you have difficulties. Finally, be aware that the PIC12F675 requires a 5V supply for programming, even though it happily runs from 3V in the circuit.

---

programmed default period of around 15 seconds.

Plastic case

The PCB is installed inside a UB5 plastic case with the piezo transducer arranged to 'fire through' a hole in the lid. You need to drill holes in the lid for the two LEDs, LDR, two switches and the piezo sound exit hole. In addition, two mounting holes, one either side of the two switches, are needed to secure the PCB to the lid, using spacers and screws.

The holes for the two LEDs and two PCB mounting holes adjacent to S1 and S2 are 3mm, the switch holes and piezo sound exit hole are 10mm and the LDR hole is 5mm. The drilling template (Fig.5) can be downloaded from the *EPE* website.

Having drilled the holes, the label can be attached. This can be downloaded from the SILICON CHIP website, printed out (preferably onto photographic paper) and affixed to the lid using either glue or neutral-cure silicone.

Another option is to print the panel onto either an A4-size 'Dataflex' sticky label (for ink-jet printers) or a 'Datapol' sticky label (for laser printers) and directly attach this to the case lid. These labels are available from **www.blanklabels.com.au** – see accompanying panel.

Once the label is in position, cut out the holes using a sharp hobby knife.

The PCB is stood off from the lid of the case using M3 × 12mm tapped spacers. M3 screws secure the PCB to these stand-offs, with countersink screws used to secure the spacers to the lid. Finally, attach the lid to the case using the four screws supplied with the case.

Note that you can keep tabs on the condition of the lithium battery condition by observing LED2. If it flashes brightly, the cell is OK. As the cell discharges, the LED will become quite dim.

Changing the settings

There are three settings that can be altered on your *Hotel Safe Alarm*: entry delay, alarm duration and the entry code. **These can only be altered after switching the alarm off by removing link JP1 and then pressing one or both switches while JP1 is reinstalled to connect power.**

Changing the entry delay and alarm period are optional and you can leave them at default settings of 15 and 60 seconds, respectively. However, you will need to set the entry code.

Entry delay

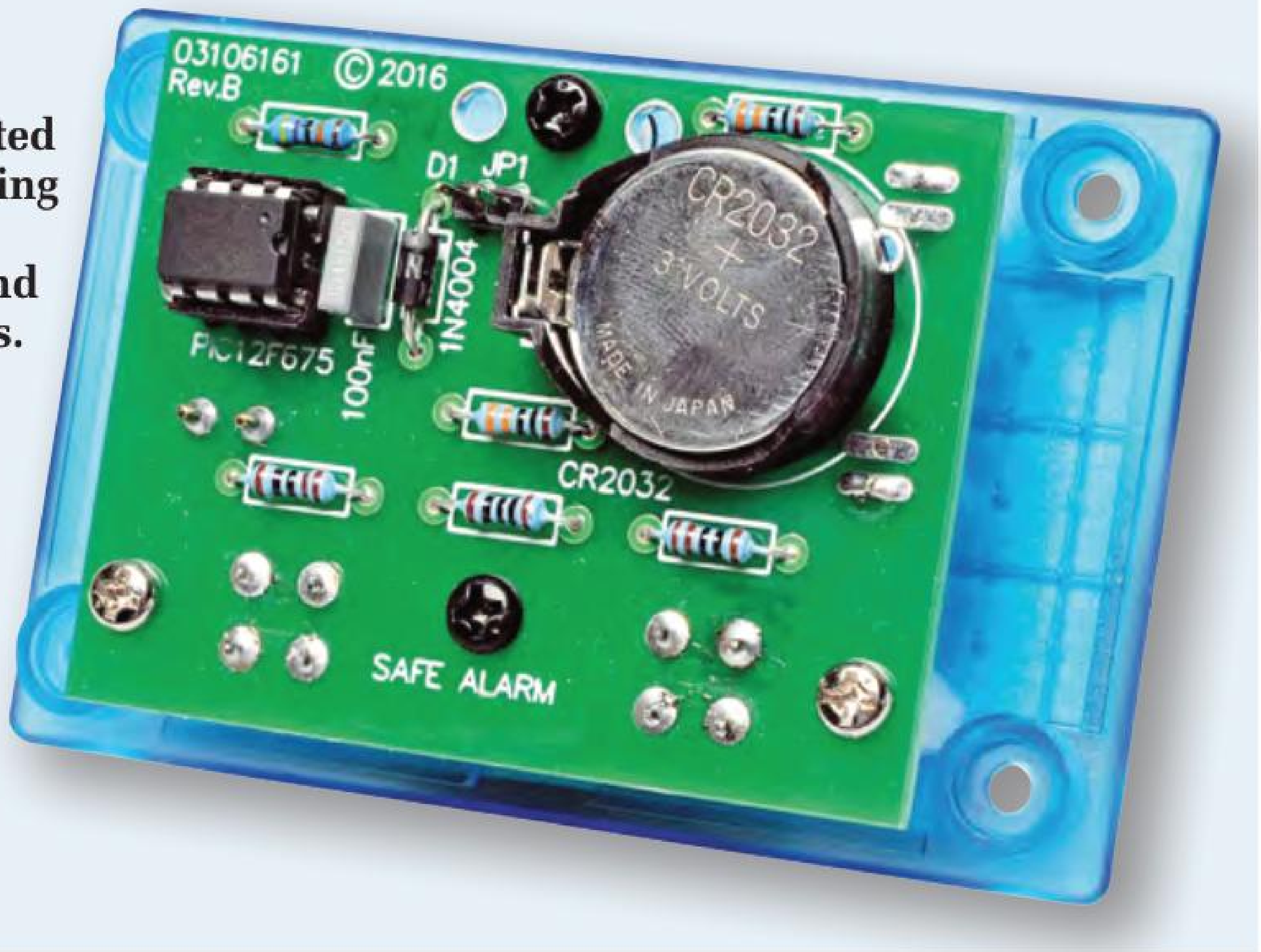
To set the entry delay, power the unit off by removing link JP1 and hold switch S1 down while JP1 is installed. Continue holding S1 down until you get a short beep from the piezo transducer (after about three seconds). Release S1 and another beep will sound.

The delay period is now entered by pressing switch S2. This starts from one second (plus the initial wake-up time of 2.3 seconds) and each time you press S2 there is a very brief double beep from the piezo to indicate the entry delay has been incremented by one second.

You can increase the delay to 60 seconds but we think that 15 seconds is quite adequate. You then store the entry delay setting by pressing S1 and this will be indicated by a short beep from the transducer.

Alarm period

The alarm period setting process is very similar to the entry delay, but now we do it with switch S2. So to set the entry delay, power the unit off by



The PCB is mounted on the case lid using two M3 × 12mm tapped spacers and M3 × 6mm screws.

Front-panel labels

The front-panel label can be made by downloading the relevant PDF file from the *EPE* website and then printing it out onto photographic paper. It can then be attached to the front panel using silicone adhesive.

Alternatively, you can print onto a synthetic Dataflex sticky label if using an inkjet printer, or onto a Datapol sticky label if using a laser printer.

(1) For Dataflex labels, go to: **www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_60&products_id=335**

(2) For Datapol labels go to: **www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_55&products_id=326**

removing link JP1 and hold switch S2 down while JP1 is installed. Continue holding S2 down until you get a short beep from the piezo transducer (after about three seconds). Release S2 and another beep will sound.

The alarm period is entered by pressing switch S1. The alarm period starts at 10 seconds and each time you press S1 there is a very brief beep from the piezo to indicate that the alarm period has been incremented by 10 seconds.

The alarm period can be adjusted from between 10 and 120 seconds in 10-second steps. When S2 is pressed, the entered alarm period will be stored and indicated by a short beep from the piezo transducer.

Entry code

The entry code comprises a sequence of presses of S1 and S2. It can be as simple as 1, 2 or 2, 1 or it could be up to eight presses, such as 1 2 2 2 1 2 1 2. Most people will want to keep it reasonably short so that it is easily remembered, such as 1221. But it can be programmed to be any sequence from 1-8 presses.

To set the entry code, power the unit off by removing link JP1 and hold both switches S1 and S2 down while JP1 is installed. Continue holding S1 and S1 down until you get a short beep from the piezo transducer (after about three seconds). Release S1 and S2 and another beep will sound.

The entry code is now entered in, with each switch press acknowledged by a brief piezo beep. The entered code will be stored after both switches are left open (ie, after none are pressed) for five seconds. An acknowledgement beep then sounds.

Using the alarm

The correct code needs to be entered during the entry delay period. Do not try to enter the code too quickly. Each time you push a button you need to wait for a short beep and then you press the next button. So, for example, if your code is 1221, you do it in this sequence: 1 beep, 2 beep, 2 beep, 1 beep. If the code is correct, the alarm will not sound (the green LED stops flashing as soon as a switch is pressed).

If you make a mistake while entering the code, or you enter it too rapidly, the alarm will sound and the safe can be closed to muffle the alarm sound.

Entering the valid code prevents the alarm sounding only if no more switches are pressed. Any further button pressing following the valid code will be greeted by an alarm.

If an intrusion is detected, both LEDs will be flashing. They will cease flashing once one of the switches is pressed to begin the entry code sequence. The LEDs turning off may even give an intruder a false hope that the code entered was correct.

The alarm is rearmed after it is placed in darkness (safe door shut). If light shines on the LDR, you must enter the code to stop the alarm from sounding.

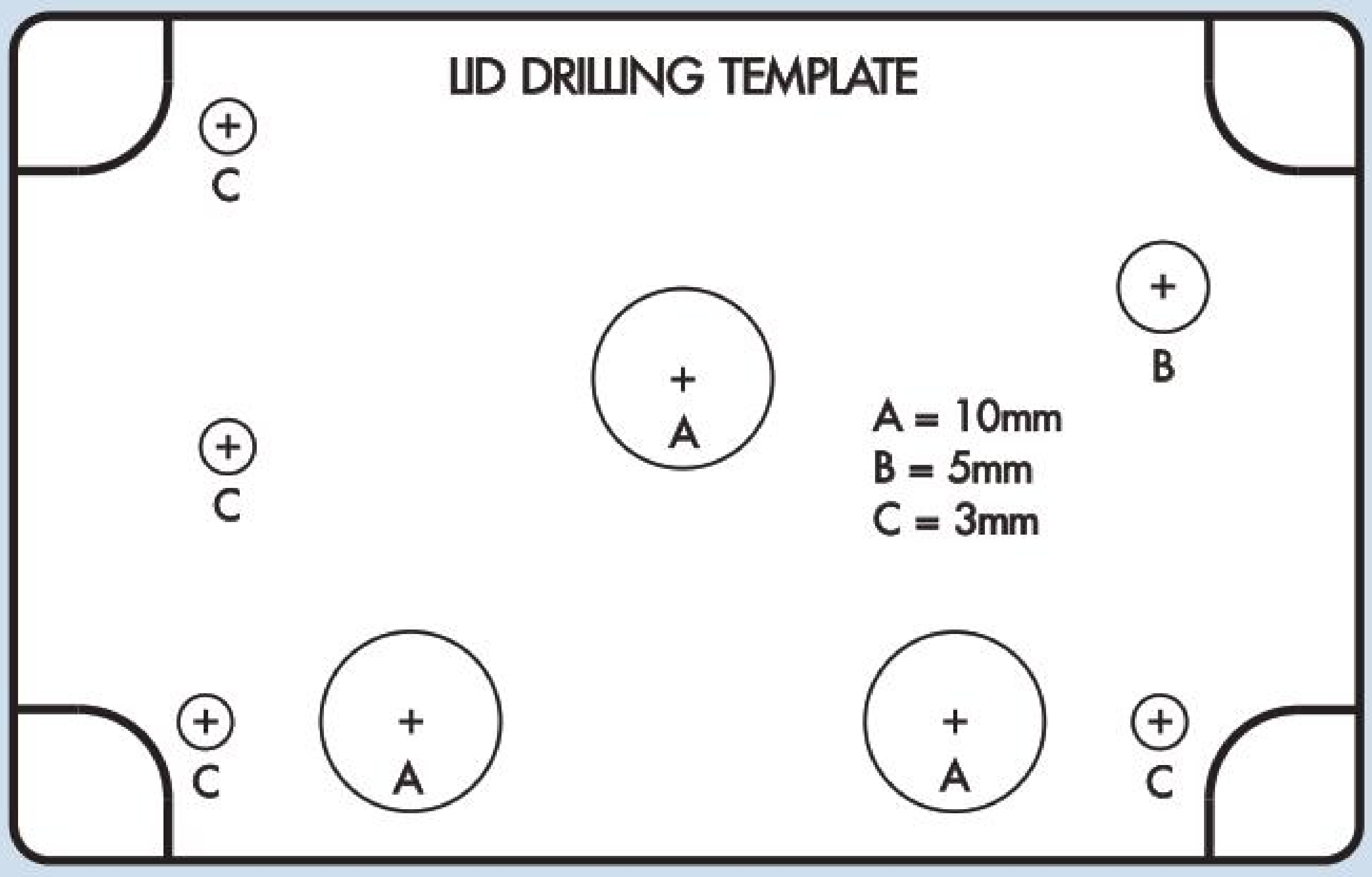


Fig.5: this drilling template can be downloaded as a PDF file from the *EPE* website.

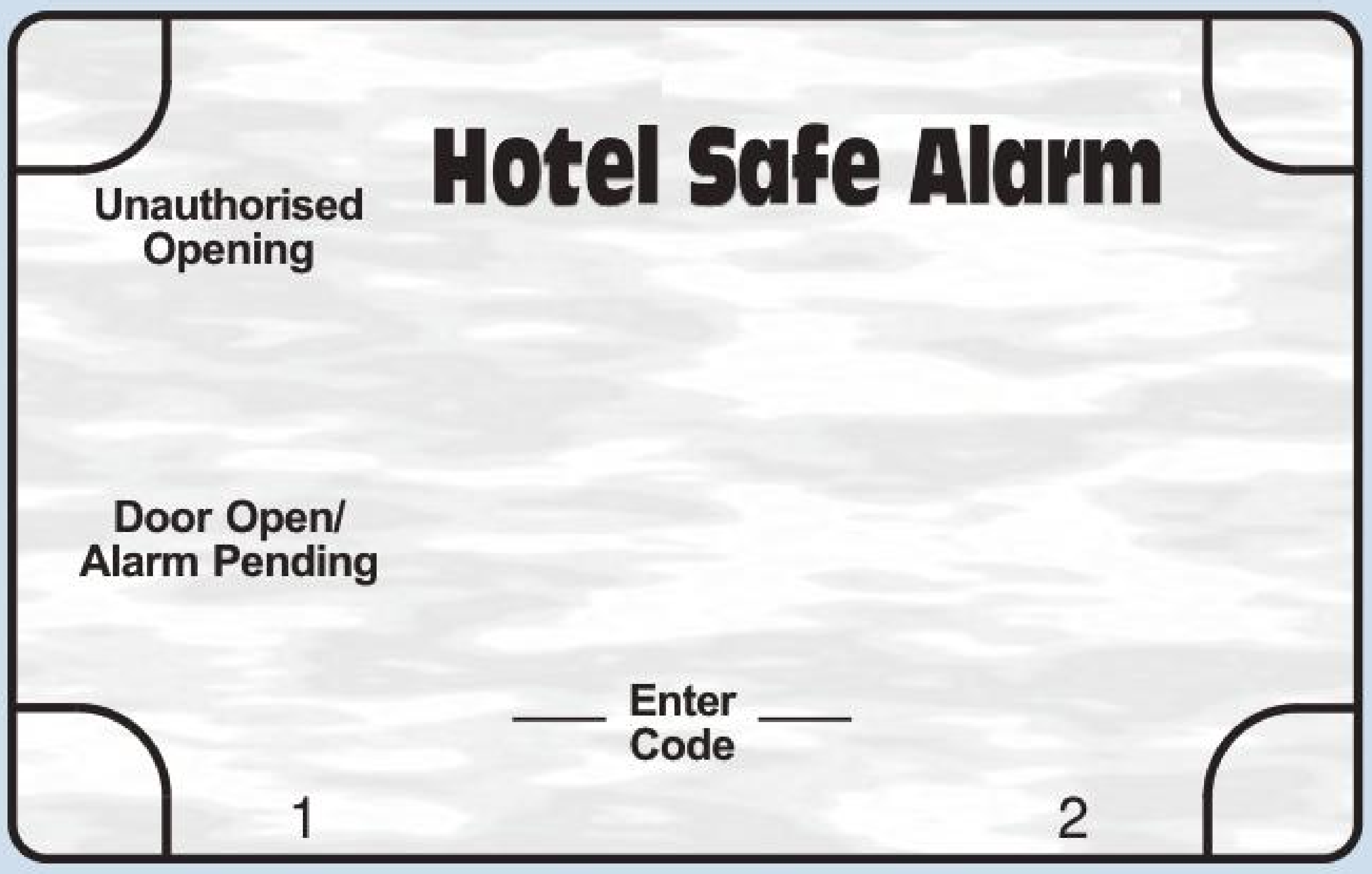


Fig.6: this front panel artwork is also available as a PDF file on the *EPE* website (see panel).

Win a Microchip Dual Mode PICtail Board

EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win a Microchip Dual Mode PICtail Board (RN-4678-PICTAIL) from *EPE*. The RN4678 PICtail is a Bluetooth Dual Mode demonstration board using the Microchip RN4678 Bluetooth Dual Mode module. The RN4678 module is a Dual mode Bluetooth module that complies with Bluetooth Core Specification 4.2.

The RN4678 is interfaced using a simple command interface over the UART. Out of the box, this versatile development board utilises its built-in USB-to-serial capability (enabled by an on-board MCP2200) to communicate with the on-board RN4678. When plugged into a PC, the board will enumerate as a Communication Device Class (CDC) serial device. Through a terminal program, users can configure and control the module and transfer data using the easy-to-use command set provided.

The RN4678 module provides an easy-to-use solution for designers looking to leverage both Bluetooth low energy (BLE) and Bluetooth Basic Rate/Enhanced Data Rate (BR/EDR) to connect new, or existing designs to the cloud. The certified module uses Bluetooth v4.2, enabling increased transmission speeds while conserving power for longer battery life.

The RN4678 module features include: • A full Bluetooth stack onboard providing the flexibility to use either ASCII commands to develop an application with the internal microcontroller (MCU) or to use an external MCU • Support for the iAP2 protocol to enable communication from accessories to iOS devices • Easily implemented security enhancements, such as white list and random address features, enabled through a single ASCII command interface • A configurable beacon feature, compatible with Eddystone and iBeacon™ technology, to generate beacons for indoor location tracking and proximity applications • Support for Microchip's BeaconThings™ technology, which automates two-way data transfer between devices when a beacon is in range, eliminating the need for a user to unlock the mobile device and launch an app • Complete FCC, IC, CE, NCC, KCC, SRRC and MIC certifications to accelerate global deployment.

WORTH
$87.00
(approx. £70.00)
EACH

MICROCHIP
RN4678

HOW TO ENTER

For your chance to win a Microchip RN4678 PICtail Board, visit:
www.microchip-comps.com/epe-nrpictail and enter your details in the online entry form.

CLOSING DATE

The closing date for this offer is 30 June 2017.

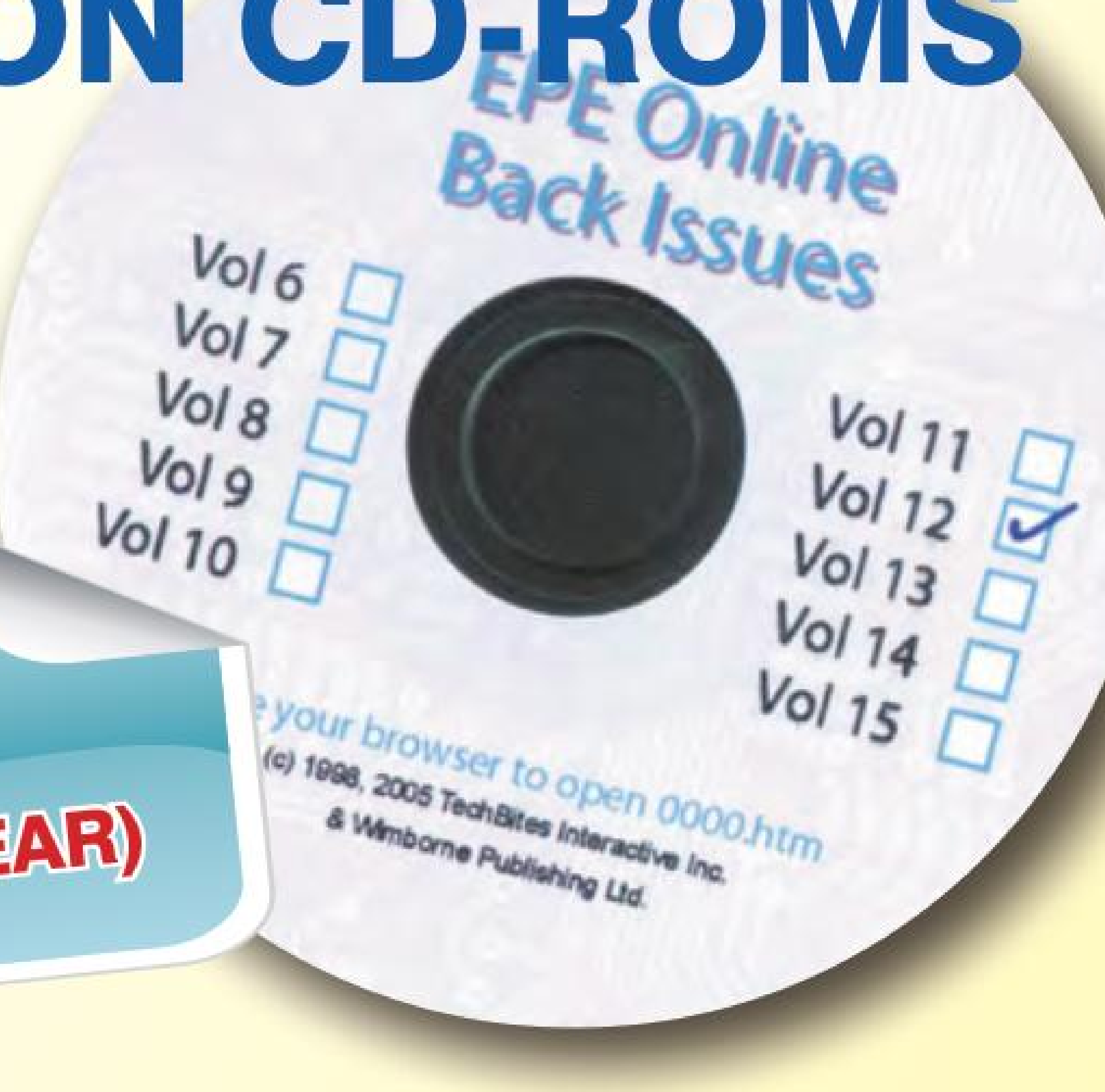
February 2017 ISSUE WINNER

Mr Bryan Hunter, who works at BH Electronics, Dundee, UK

He won a Microchip dsPICDEM MCLV-2 Development Board, valued at £160.00

STORE YOUR BACK ISSUES ON CD-ROMS

Order on-line from
www.epemag.com (go to the UK store)
or by phone, fax, email or post


EPE Online
Back Issues
Vol 6
Vol 7
Vol 8
Vol 9
Vol 10
Vol 11
Vol 12
Vol 13
Vol 14
Vol 15
your browser to open 0000.htm
(c) 1998, 2005 TechBites Interactive Inc.
& Wimborne Publishing Ltd.

ONLY
£16.45
(£29.95 FOR 5 YEAR)
each including VAT and p&p

VOL 1: **BACK ISSUES** – January 1999 to June 1999
Plus some bonus material from Nov and Dec 1998
VOL 2: **BACK ISSUES** – July 1999 to December 1999
VOL 3: **BACK ISSUES** – January 2000 to June 2000
VOL 4: **BACK ISSUES** – July 2000 to December 2000
VOL 5: **BACK ISSUES** – January 2001 to June 2001
VOL 6: **BACK ISSUES** – July 2001 to December 2001
VOL 7: **BACK ISSUES** – January 2002 to June 2002
VOL 8: **BACK ISSUES** – July 2002 to December 2002
VOL 9: **BACK ISSUES** – January 2003 to June 2003
VOL 10: **BACK ISSUES** – July 2003 to December 2003
VOL 11: **BACK ISSUES** – January 2004 to June 2004
VOL 12: **BACK ISSUES** – July 2004 to December 2004
VOL 13: **BACK ISSUES** – January 2005 to June 2005
VOL 14: **BACK ISSUES** – July 2005 to December 2005
VOL 15: **BACK ISSUES** – January 2006 to June 2006
VOL 16: **BACK ISSUES** – July 2006 to December 2006
VOL 17: **BACK ISSUES** – January 2007 to June 2007
VOL 18: **BACK ISSUES** – July 2007 to December 2007
VOL 19: **BACK ISSUES** – January 2008 to June 2008
VOL 20: **BACK ISSUES** – July 2008 to December 2008
VOL 21: **BACK ISSUES** – January 2009 to June 2009
VOL 22: **BACK ISSUES** – July 2009 to December 2009

FIVE YEAR
DVD/CD-ROMs
NOW AVAILABLE

FIVE YEAR CD/DVD-ROMs

No.1 – Jan '03 to Dec '07
No.2 – Jan '04 to Dec '08
No.3 – Jan '05 to Dec '09
No.4 – Jan '06 to Dec '10
No.5 – Jan '07 to Dec '11
No.6 – Jan '08 to Dec '12
No.7 – Jan '09 to Dec '13
No.8 – Jan '10 to Dec '14
No.9 – Jan '11 to Dec '15

NEW
No.9

NOTE: These DVD/CD-ROMs are suitable for use on any PC with a DVD/CD-ROM drive. They require Adobe Acrobat Reader (available free from the Internet – **www.adobe.com/acrobat**)

WHAT IS INCLUDED

All volumes include the *EPE Online* content of every listed issue. **Please note that we are unable to answer technical queries or provide data on articles that are more than five years old. Please also ensure that all components are still available before commencing construction of a project from a back issue.**

VOL 23: **BACK ISSUES** – January 2010 to June 2010
VOL 24: **BACK ISSUES** – July 2010 to December 2010
VOL 25: **BACK ISSUES** – January 2011 to June 2011
VOL 26: **BACK ISSUES** – July 2011 to December 2011
VOL 27: **BACK ISSUES** – January 2012 to June 2012
VOL 28: **BACK ISSUES** – July 2012 to December 2012
VOL 29: **BACK ISSUES** – January 2013 to June 2013
VOL 30: **BACK ISSUES** – July 2013 to December 2013
VOL 31: **BACK ISSUES** – January 2014 to June 2014
VOL 32: **BACK ISSUES** – July 2014 to December 2014
VOL 33: **BACK ISSUES** – January 2015 to June 2015

NEW
Vol.34

VOL 34: **BACK ISSUES** –
July 2015 to December 2015

BACK ISSUES DVD/CD-ROM ORDER FORM

Please send me the following Back Issue DVD/CD-ROMs.

Volume Numbers:. . . . .
. . . .

Price £16.45 each, £29.95 for Five Year DVD/CD-ROMs – includes postage to anywhere in the world.

Name . . . .
. . . .

Address . . . .
. . . .
. . . .

Post Code. . . . .

☐ I enclose cheque/P.O./bank draft to the value of £ . . . .

☐ please charge my Visa/Mastercard £ . . . .

Card No. . . . .

Card Security Code . . . . (The last 3 digits on or just under the signature strip)

Valid From . . . . Expiry Date . . . .

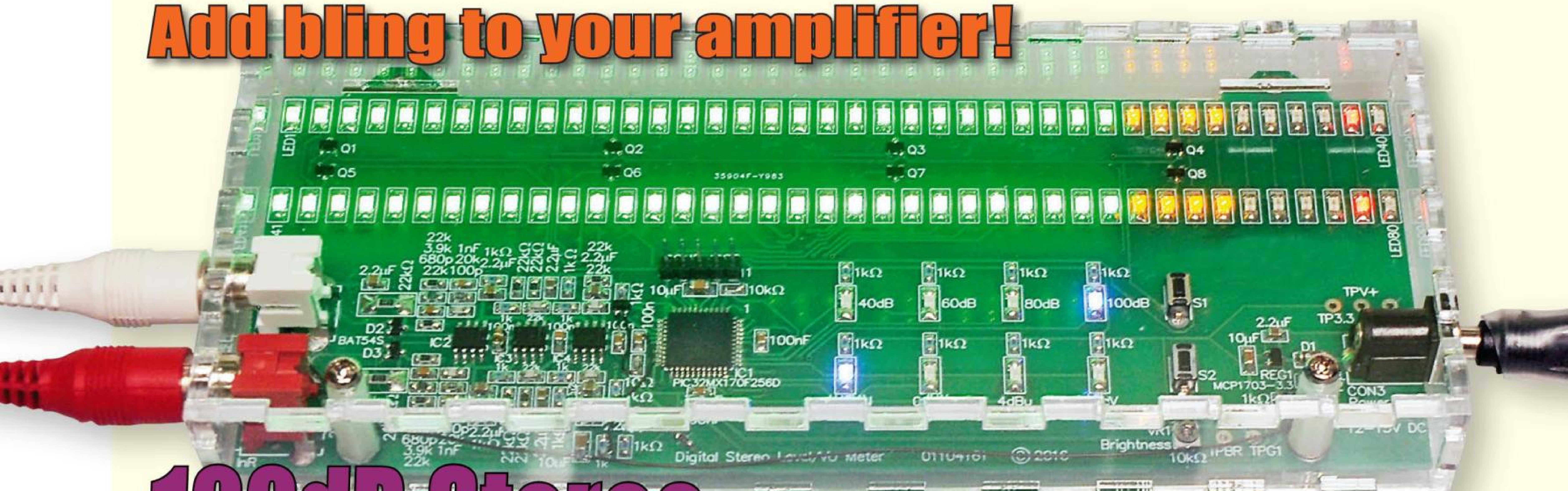
SEND TO: **Everyday Practical Electronics,**
Wimborne Publishing Ltd., 113 Lynwood Drive, Merley,
Wimborne, Dorset BH21 1UU.

Tel: 01202 880299. Fax: 01202 843233.
E-mail: orders@epemag.wimborne.co.uk

Payments must be by card or in £ Sterling – cheque or bank draft drawn on a UK bank.

Normally posted within seven days of receipt of order.

Add bling to your amplifier!



100dB Stereo LED Audio Level/VU Meter

Part 1: By Nicholas Vinen

Give your Hi-Fi system some WOW factor with this spectacular *Stereo VU Meter*. It uses 80 high-brightness SMD LEDs to give any stereo amplifier/mixer a highly colourful dual-bargraph display, which simultaneously shows the average audio signal level plus peak levels. And it can display signal ranges up to a whopping 100dB.

YEARS AGO, some big and expensive stereo power amplifiers sported large dual VU meters to indicate the power levels in both channels. But while they looked quite impressive, they were a bit of a gimmick since their analogue meter movements could only display signal averages. They certainly weren't fast enough to display the peak signal levels, which would have been a big advantage. And of course, professional audio mixing desks also typically had VU metering – but these days it is usually based on LED arrays, which show average and peak signal levels, just like this design!

This *LED VU Meter* uses 80 high-brightness SMD LEDs to give a dual bargraph display of the average audio signal level, with dots indicating the peak levels. It can be configured to display a dynamic range between 40dB and 100dB, depending on your application. It's suitable for monitoring line-level signals or power amplifier outputs.

Whether or not you actually need to add this meter to a piece of equipment, once you see it in action, you'll want to fit it in anyway!

If you are a keen Hi-Fi enthusiast, this VU meter can show you how much headroom you have from your audio amplifier; ie, it can show how many more decibels it is capable of delivering before clipping and this is indicated with the peak dot display.

It can also be used when recording or mixing, to ensure that the incoming audio signal(s) are consistent with each other and none of them are going to overload and cause excessive distortion or loss of dynamic range.

One important feature of an audio level meter is that it should update relatively fast, so you can see the dynamic nature of the signal, but not so fast that your eye can't track it. Traditional 'VU meters' were designed with a response time of 300ms (to 99%), to give a reasonable impression of signal loudness and also because the needle could only move so fast.

Since this meter uses digital technology, it can show the peak and average level simultaneously and the peak level can have a fast rise time and a slow fall time. The fast rise-time allows the circuit to 'catch' those very fast and short peaks, while the slow fall time allows you to better see them when they occur.

For purists, we've implemented a VU-style meter mode so you can stick with the traditional 300ms rise/fall time averaging if that is what you want.

The two bargraphs, one for each stereo channel, consist of 40 individual LEDs. With a dynamic range of 40dB, that means each LED lights for a 1dB increase in signal level. If you select the 60dB range, that gives 1.5dB/LED; the 80dB range gives 2dB/LED; and the 100dB range, 2.5dB/LED. These are SMD LEDs with rectangular lenses roughly 2mm square – and they are incredibly bright pin-points. We've included an on-board pot to reduce the brightness for a darker room.

The meter has a green/yellow/amber/red colour scheme. The colour shifts simply give a warning that you are approaching the clipping level.

A pushbutton can select one of four full-scale signal levels: –10dBV, 0dBV,

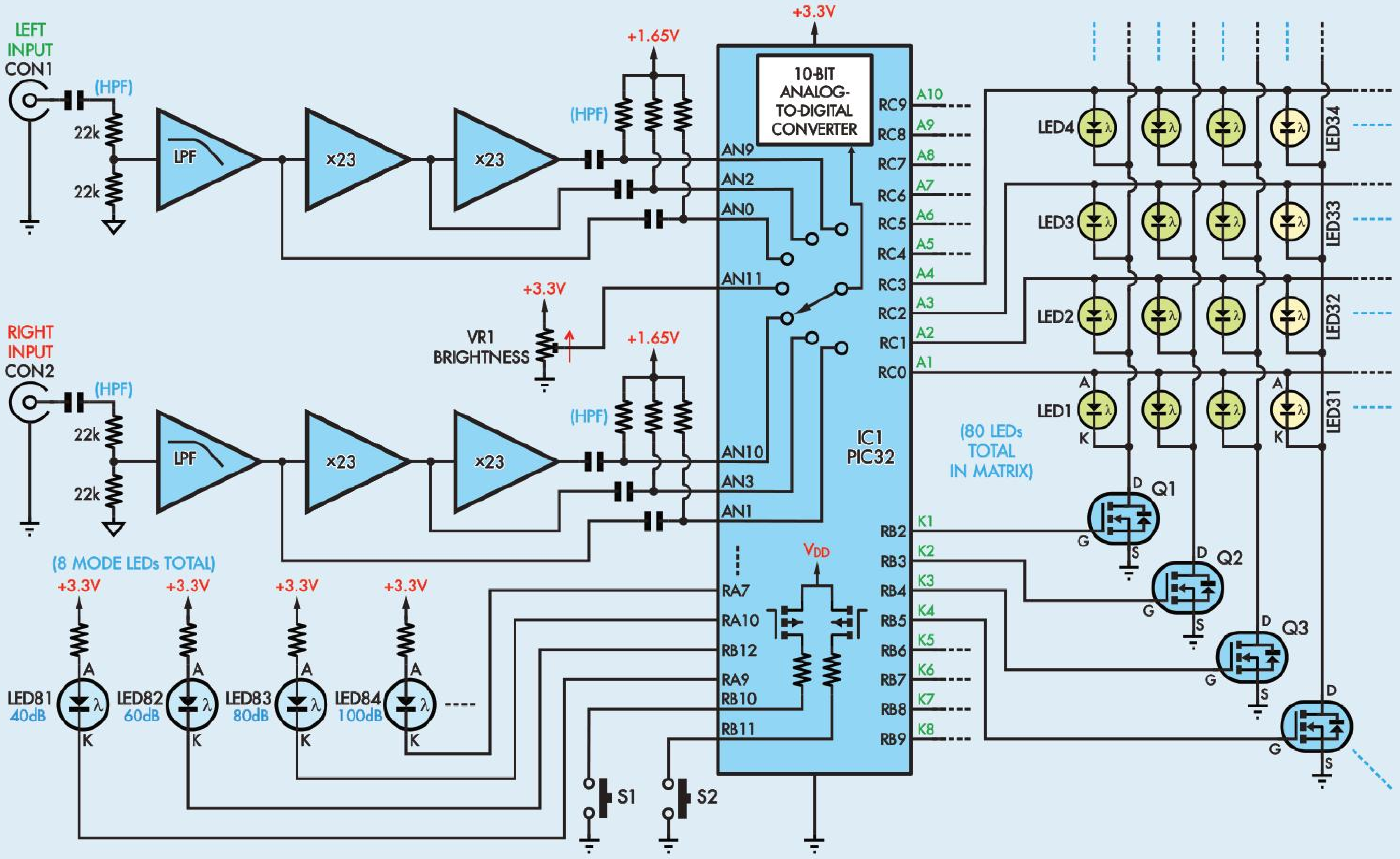

LEFT INPUT
CON1
RIGHT INPUT
CON2
(HPF)
22k
22k
LPF
x23
x23
+1.65V
+3.3V
10-BIT ANALOG-TO-DIGITAL CONVERTER
AN9
AN2
AN0
AN11
AN10
AN3
AN1
RC9
RC8
RC7
RC6
RC5
RC4
RC3
RC2
RC1
RC0
A10
A9
A8
A7
A6
A5
A4
A3
A2
A1
VR1 BRIGHTNESS
IC1 PIC32
(80 LEDs TOTAL IN MATRIX)
LED1
LED2
LED3
LED4
LED31
LED32
LED33
LED34
A
K
D
G
S
Q1
Q2
Q3
RB2
RB3
RB4
RB5
RB6
RB7
RB8
RB9
K1
K2
K3
K4
K5
K6
K7
K8
VDD
RA7
RA10
RB12
RA9
RB10
RB11
(8 MODE LEDs TOTAL)
LED81 40dB
LED82 60dB
LED83 80dB
LED84 100dB
S1
S2

Fig.1: a simplified circuit showing how the *Stereo VU Meter* works. The audio signals (left and right channels) first pass through a high-pass filter/attenuator, followed by an active low-pass filter and two gain stages. The signals before and after the gain stages are then fed to microcontroller IC1, which does the peak and average calculations, then drives a multiplexed LED display using outputs RB2-RB9 to control eight cathode-driving MOSFETs (Q1-Q8) and outputs RC0-RC9 to drive the LED anodes directly.

+4dBu or +7dBV. Different equipment will have different line levels and one of these will suit most devices: –10dBV (316mV RMS) for some battery-powered consumer equipment such as iPods and mobile phones, 0dBV (1V RMS) for other consumer equipment, +4dBu (1.228V RMS) for some professional gear and +7dBV (2.24V RMS) for CD, DVD and Blu-ray players and some other equipment.

You can make fine or coarse adjustments to levels or set your own based on reference signals fed into the unit.

The unit runs from a 12-15V DC supply, so it can be powered from a small plugpack, 12V lead-acid battery or a low-voltage internal rail in an amplifier or similar equipment. It only draws about 50-150mA when operating, depending on the LED brightness setting.

The PCB includes RCA input sockets and a DC socket for power, so it can be used in its own case with a clear lid or incorporated into another piece of equipment and hard-wired in place.

The metering circuit's signal-to-noise ratio is good enough to allow you to use the 100dB range with a +7dBV reference level and use the whole range of the device. The 100dB range can also be used with a lower reference level but you will need to use the noise-nulling feature to get a blank display with no signal. This feature is useful to subtract source noise (eg, from the driving equipment) from the display when operating in the higher dynamic range settings.

Other features include: software adjustments to cancel out variation in brightness between different colour LEDs; peak+average, peak-only and average-only modes; non-volatile mode and calibration settings; and mode indicator LEDs (see specifications panel for more details).

Principle of operation

Fig.1 is a simplified circuit diagram which gives an overview of the operation of the unit. It's based on 32-bit microcontroller IC1, which operates at 40MHz and incorporates a 10-bit analogue-to-digital converter (ADC) with an input multiplexer. Seven of the analogue inputs are used.

The two 40-LED bar displays (80 LEDs in total) are multiplexed in eight groups, each group of 10 sharing a common cathode that is driven by one of eight N-channel MOSFETs Q1-Q8, which are in turn controlled by the microcontroller's outputs RB2-RB9. The LED anodes are driven directly by outputs RC0-RC9. Only a 4x4 portion of the 8x10 LED matrix is shown, but you can see the general arrangement.

The eight indicator LEDs (LEDs81-88, four shown in Fig.1) are driven directly at their cathodes from eight microcontroller outputs. The anodes connect to the 3.3V supply via current-limiting resistors.

Actually, there are no current-limiting resistors for the matrixed LEDs, as such. Instead, their current is limited by the internal impedance of the transistors which drive the micro's output pins, in combination with a software-limited on-time/duty cycle.

This results in a current drive of around 1.2mA/LED at full brightness, for a total LED bar current of around 100mA. Since this is split between 10

Features and specifications

- Display: two rows of 40 SMD 3216 (1206 imperial) LEDs
- Input signal: up to 2.33V RMS (+7.36dBV) or higher with changed resistors (eg, to suit power amplifier outputs)
- Frequency response: 5Hz-20kHz, –3dB (see Fig.2)
- Input impedance: approximately 37kΩ
- Modes: peak+average (dot/bar), average only (bar), peak only (bar), VU-style (peak+average or average only)
- Meter range: selectable 40dB, 60dB, 80dB or 100dB (1dB/LED, 1.5dB/LED, 2dB/LED or 2.5dB/LED)
- Reference level: selectable –10dBV (316mV RMS), 0dBV (1V RMS), 4dBu (1.228V RMS), 7dBV (2.24V RMS) or custom levels (per-channel)
- Power supply: 12-15V DC, ~50-150mA
- Brightness adjustment: 10-100% via potentiometer (onboard trimpot or chassis-mounted)
- Inputs: RCA sockets for signals, 2.1mm or 2.5mm ID DC socket for power
- Other features: LED brightness matching for different colour LEDs in display, external/internal noise nulling, peak/average calculation period adjustment, supply reverse-polarity protection

anode drive pins, that means around 10mA per pin. (IC1 has an 'Absolute Maximum' rating of 15mA/pin and an overall limit of 200mA).

The analogue signals are fed into CON1 and CON2 at left. The circuit is designed for line-level signals with a maximum level ranging from around 316mV RMS (–10dBV) up to 2.33V RMS (+7.35dBV), to suit most consumer equipment and also some professional audio gear. The input divider resistors can be changed to allow much higher signal amplitudes, eg, to suit the outputs of a power amplifier. Further adjustments in full-scale level can be made using the pushbutton interface.

The signals are AC-coupled and attenuated to no more than 1.16V RMS (3.3V peak-to-peak) using a resistive divider. This AC coupling serves as a high-pass filter (HPF) to remove DC and very-low-frequency signals (<5Hz). Note that there is another HPF at the ADC inputs of IC1.

There is also an active low-pass 3-pole filter inserted immediately after the resistive divider, built around a dual op amp (for both channels) with a –3dB point of 20kHz. It provides a fast roll-off, with around 20dB of attenuation by 40kHz and also incorporates RF filtering. The overall effect of the low-pass and high-pass filtering on the frequency response is shown in Fig.2.

Analogue-to-digital conversion

The signals from the output of the low-pass filters are fed directly to a pair of analogue inputs on IC1. These signals are amplified by 23 times and the amplified signal is fed to another pair of analogue inputs. This signal is further amplified by another 23 times (ie, 529 times total) and fed to a third pair of analogue inputs. The seventh analogue input is used to sense the position of the brightness pot.

The micro samples all seven inputs, with the six signal inputs sampled continuously at around 40kHz and the brightness pot sampled every millisecond or so. For each channel, the software uses whichever signal gives the most accurate reading, ie, the unamplified input for higher level signals and one of the amplified inputs for lower level signals. This greatly improves its dynamic range, given that it only has a 10-bit ADC.

A perfectly noiseless 10-bit ADC would give a dynamic range of around $20\log_{10}(2^{10})$ = 60dB. CD-quality audio uses 16 bits and has a dynamic range of $20\log_{10}(2^{16})$ = 96dB, so it is desirable for our VU meter to have a similar dynamic range.

We could have used an external ADC, however these mostly come in fine-pitch SMD packages and can be a little expensive. Instead, we have used the two gain stages described above, in combination with software input switching depending on signal level, to effectively provide the extra bits needed to achieve a 100dB dynamic range while only using the existing 10-bit ADC.

Two momentary pushbuttons, S1 and S2, are used to configured the unit. These can be used to change a variety of settings, such as the meter range, reference level, peak/averaging mode, level calibration, brightness calibration and so on. When pressed, S1 pulls input RB10 low, while S2 pulls RB11 low. These are held high by internal pull-up resistors which are enabled by the firmware.

In essence, the circuit concept is relatively simple, but a lot of the work, including the peak and RMS calculations, averaging, display multiplexing and so on is done by IC1's firmware.

Full circuit description

The full circuit diagram for the *Stereo VU Meter* is shown in Fig.3. The left and right channel input circuitry is identical, so we will describe the left channel only, with part numbers for the right channel in brackets.

From CON1 (CON2), the signal is AC-coupled via a 2.2µF ceramic capacitor and DC biased to +5.6V via a 22kΩ resistor. The 5.6V rail is half the 11.2V op amp supply, allowing the signal to swing symmetrically between the op amp supply rails (ie, between 0V and 11.2V).

This 22kΩ bias resistor forms a divider in combination with the input series resistor, attenuating the input signal by half, while keeping the input impedance relatively high at around 37kΩ. As explained later, these resistor values can be changed to allow the unit to handle higher signal levels.

The 2.2µF capacitor and 22kΩ series resistor form a high-pass filter for the input signal. Further high-pass filtering is also performed by the software.

Dual SMD Schottky diode D2 (D3) clips the input signal, should it go below ground or above the 11.2V op amp supply rail. The BAT54S has a low forward voltage of around 0.3V, so it will conduct before the junctions in the op amp's inputs.

Low-pass filter

The following active 3-pole low-pass filter is built around an NE5532D low-noise op amp IC2a (IC2b). The first section of this filter, consisting of a 3.9kΩ series resistor and 680pF capacitor, also serves to attenuate much

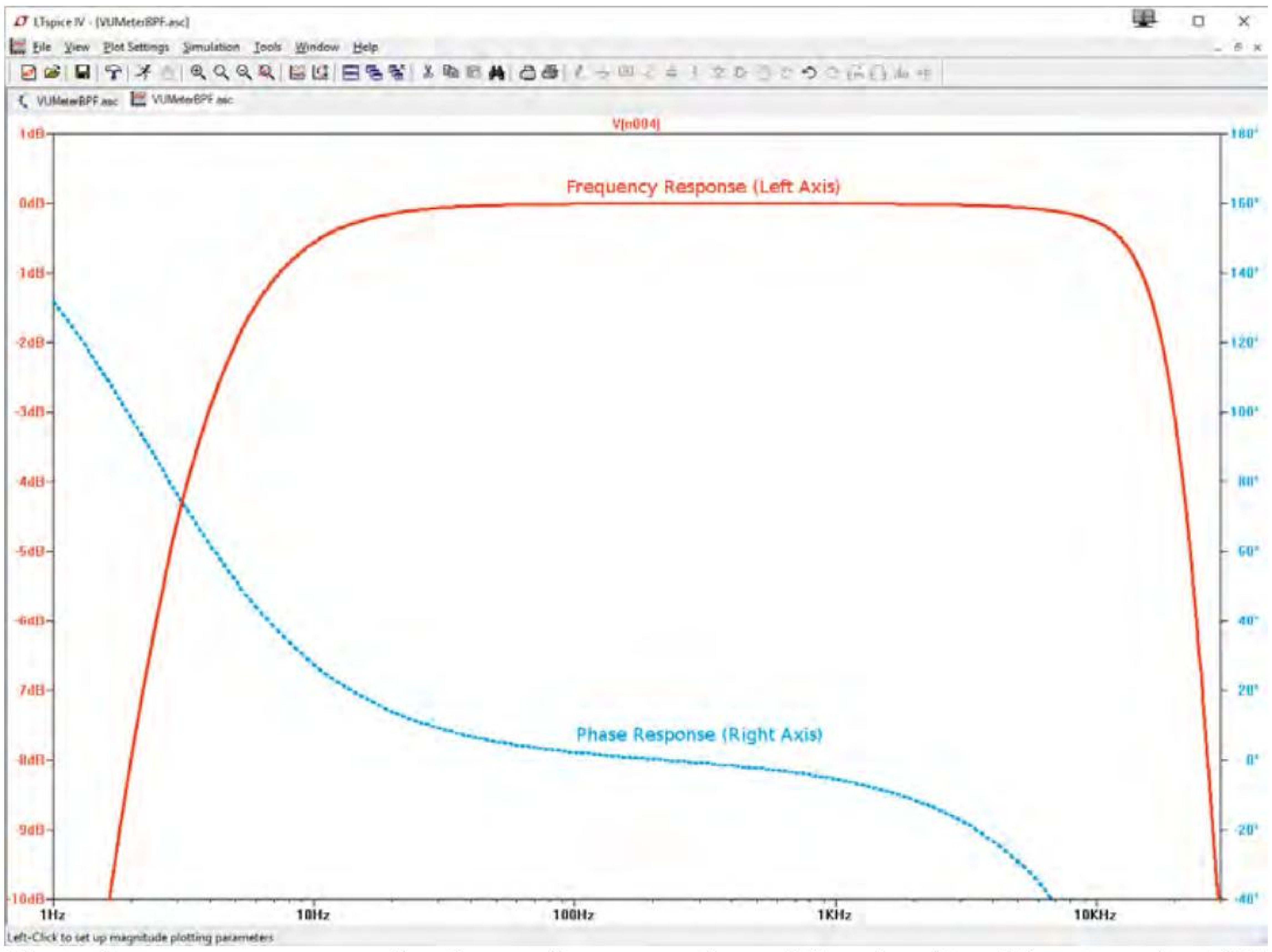


Fig.2: frequency response for the analogue portion of the circuitry. The steep (–18dB/octave) roll-off of the low-pass filter can be seen, with virtually no attenuation below 15kHz, –3dB at 20kHz, –10dB at 30kHz and around –20dB at 40kHz (not visible). The bass roll-off is from two passive high-pass RC filters and gives a –3dB point of 5Hz and –10dB at around 1.6Hz.

higher frequency signals (eg, AM radio) which may have been picked up by the signal leads.

This filter is a special case of the Sallen-Key active low-pass filter (see **www.beis.de/Elektronik/Filter/Act3PoleLP.html**) which gives a –18dB/octave roll-off using a single active device (in this case, an op amp). The values were chosen carefully, to give a near-flat bandpass response (ie, Butterworth characteristic) using E24-series resistors and E12-series capacitors (see Fig.2).

Note that the 3.9kΩ resistor was chosen with the 11kΩ impedance of the preceding divider being taken into account. In other words, the resistance between the input and the 680pF capacitor should be 14.9kΩ; the two 22kΩ resistors are effectively in parallel when considering the impedance feeding the RC filter, hence we subtracted 11kΩ from 14.9kΩ to get 3.9kΩ.

The filtered output from pin 1 of IC2a (pin 7 of IC2b) is fed to analog input AN0 (AN1) of micro IC1 via a 2.2µF capacitor and 1kΩ resistor. This resistor, in combination with dual Schottky diode D4 (D7), prevents the voltage at the micro's input from going below –0.3V or above +3.6V. In addition, a 22kΩ resistor provides a DC bias of 1.65V, ie, the halfway point of the micro's 3.3V supply. This keeps the signal within the ADC's input range of 0-3.3V for input signals of up to 2.33V RMS (keeping in mind the 2:1 input attenuation).

While the micro has internal clamp diodes to protect its inputs and it might seem like D4 and D7 are overkill, we discovered an interesting 'feature' of the PIC32 series – if you drive an analogue input pin beyond its supply rails, even within its input current rating, the chip may reset! Hence these clamp diodes are mandatory, and as before, Schottky diodes are used because they will conduct before the IC's internal semiconductor junctions.

Gain stages

IC3a (IC3b) and IC4a (IC4b) are both configured as non-inverting amplifiers with a gain of 23, set by the ratio of the 22kΩ and 1kΩ feedback resistors. A 100pF capacitor across the 22kΩ resistor rolls off its frequency response, reducing high-frequency noise gain and making the whole circuit quieter.

To achieve the 100dB dynamic range relative to 7dBV (2.24V RMS), we need less than 22.4µV RMS input-referred noise throughout the entire system. That is why we're using NE5532 low-noise op amps.

The total system gain from the input to analogue input AN9 (AN10) is 0.5 × 23 × 23 = 264.5. A –100dB (2.24µV) input signal will thus be amplified to 6mV RMS. The 10-bit ADC senses voltage steps of 3.3V/1024 = 3.2mV. So this level of signal can be (just) measured by IC1.

Driving the LEDs

Driving the 80 LEDs in the VU meter takes up a total of 18 output pins. Each bar of 40 LEDs is broken up into four groups of 10 and the cathodes of the LEDs in each group are tied together. These cathodes are driven by one of logic-level MOSFETs Q1-Q8, which are in turn driven from microcontroller outputs RB2-RB9 (pins 23, 24, 33, 41-44 and 1 of IC1 respectively). Because these MOSFETs have such a small gate charge, no extra circuitry is required. Each MOSFET is switched on in turn for around 1.6ms.

When Q1 is switched on (ie, pin 23 of IC1 [RB2] is high), LED1-LED10 can be lit when their respective anodes are driven high. The anodes are driven by outputs RC0-RC9 of micro IC1 (pins 25-27, 36-38 and 2-4 respectively).

The cathodes of LEDs 81-88 are driven by microcontroller outputs RA9, RB12, RA10, RA7, RA8, RA3, RA2 and RA4 respectively (pins 35, 10, 12, 13, 32, 31, 30 and 34). The 1kΩ current-limiting resistors result in a drive of around 0.5mA each.

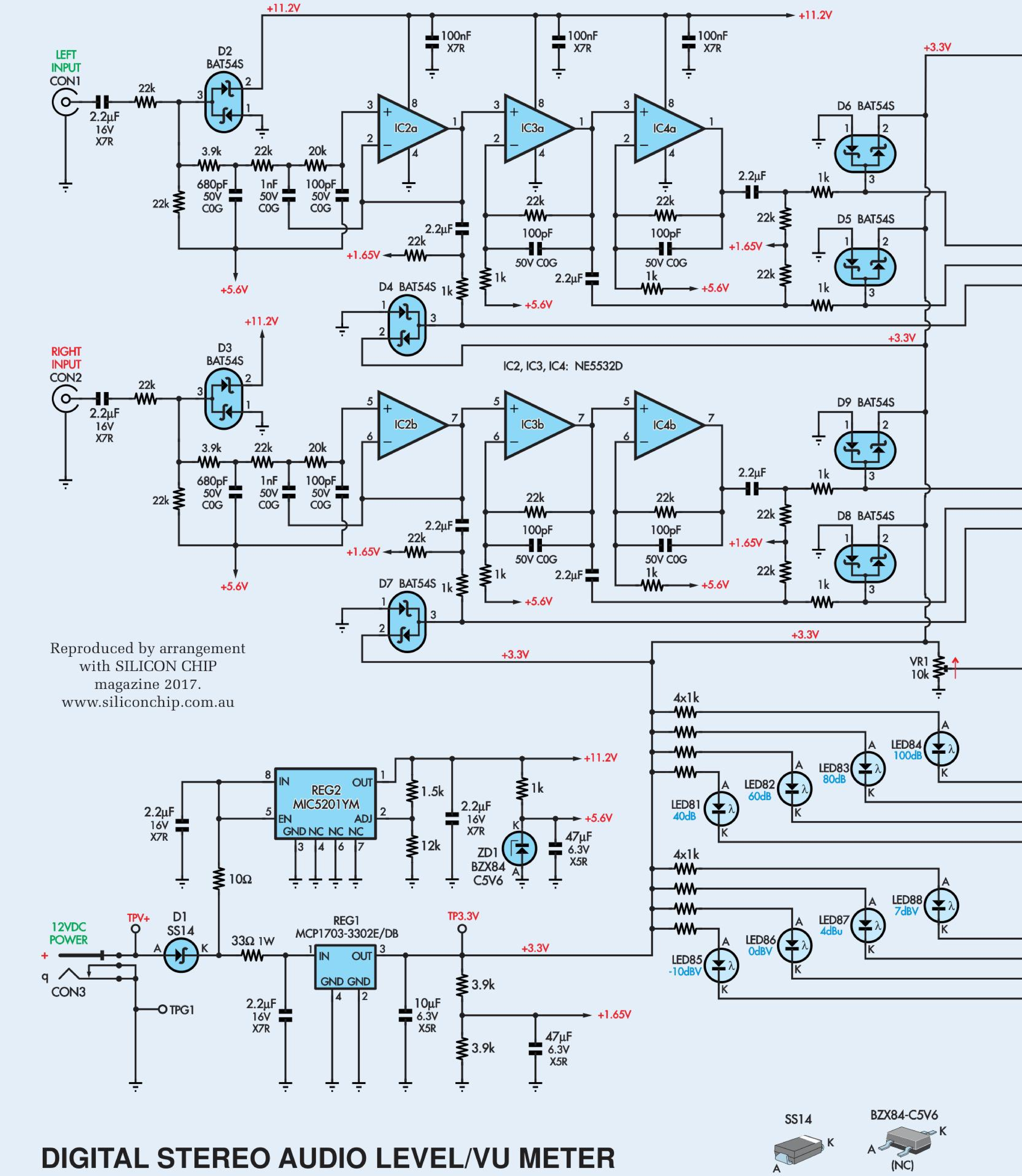
Controls

Tactile pushbutton switch S1 is used to cycle through the available meter ranges (and performs other functions when pressed and held, or pressed in combination with S2). Similarly, switch S2 cycles through the four different reference levels. Their associated input pins, RB10 and RB11 (pins 8 and 9), are also used for programming and debugging IC1. There is no conflict as long as neither switch is pressed when the in-circuit serial programming (ICSP) tool plugged into CON5 is being used.

Brightness pot VR1 forms a voltage divider across the 3.3V supply and the voltage at its wiper is sensed via analogue input AN11 (pin 11) of IC1. The brightness is controlled by adjusting the LED matrix anode-drive period.

Power supply

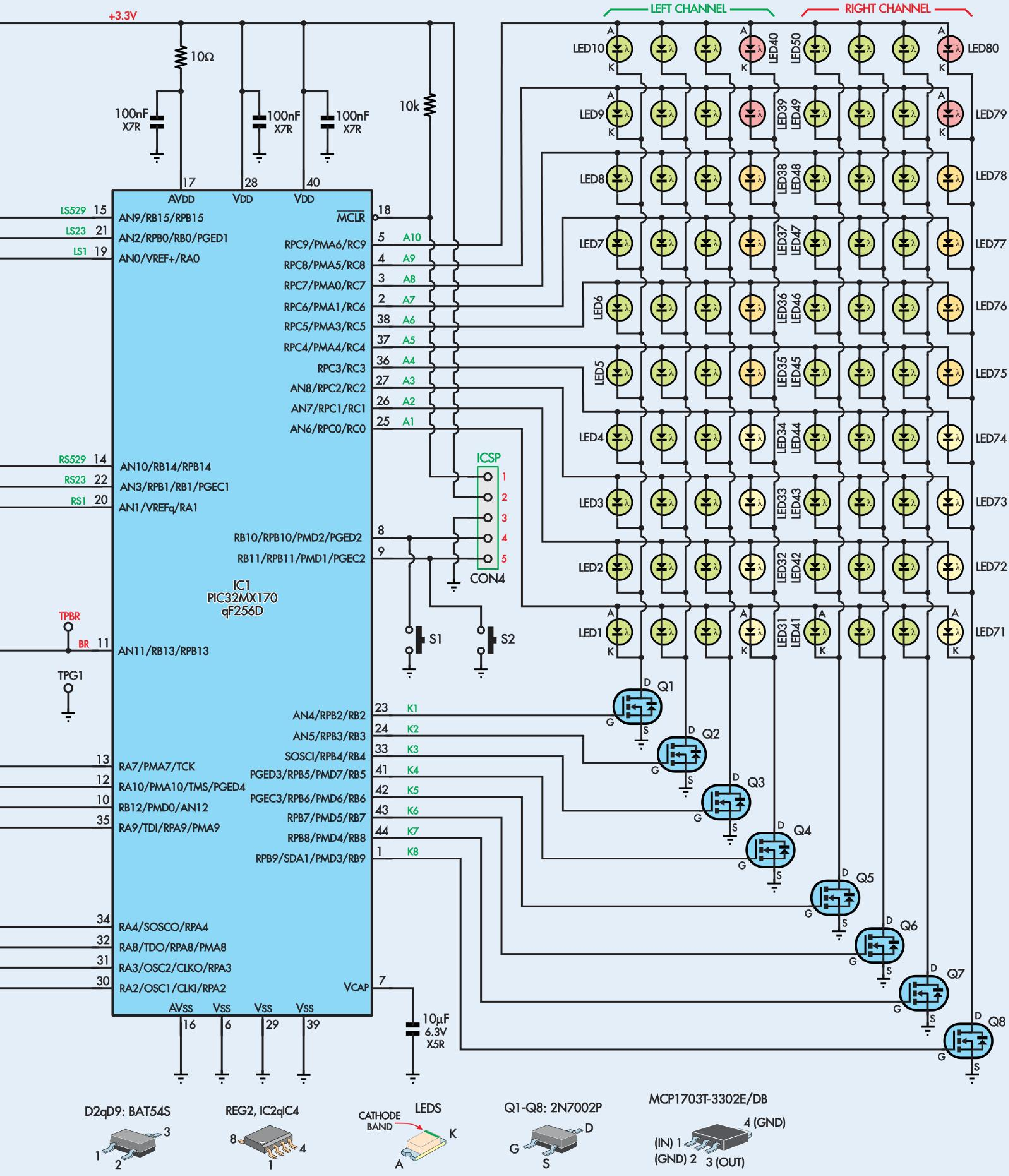
The power supply is relatively simple and uses only linear regulators, but its design is critical to achieve the stated performance. 12-15V DC is applied to


LEFT INPUT
CON1
2.2µF 16V X7R
22k
D2 BAT54S
+11.2V
3.9k
680pF 50V C0G
1nF 50V C0G
20k
100pF 50V C0G
+5.6V
+1.65V
IC2a
IC3a
IC4a
100nF X7R
100pF 50V C0G
D4 BAT54S
1k
D6 BAT54S
D5 BAT54S
+3.3V
RIGHT INPUT
CON2
D3 BAT54S
IC2b
IC3b
IC4b
D7 BAT54S
D9 BAT54S
D8 BAT54S
IC2, IC3, IC4: NE5532D
VR1 10k
4x1k
LED81 40dB
LED82 60dB
LED83 80dB
LED84 100dB
LED85 -10dBV
LED86 0dBV
LED87 4dBu
LED88 7dBV
REG2 MIC5201YM
IN
OUT
EN
ADJ
GND NC NC NC
1.5k
12k
2.2µF 16V X7R
1k
ZD1 BZX84 C5V6
47µF 6.3V X5R
10Ω
12VDC POWER
CON3
TPV+
D1 SS14
TPG1
33Ω 1W
REG1 MCP1703-3302E/DB
GND GND
TP3.3V
10µF 6.3V X5R
3.9k
SS14
BZX84-C5V6
A
K
(NC)

Reproduced by arrangement
with SILICON CHIP
magazine 2017.
www.siliconchip.com.au

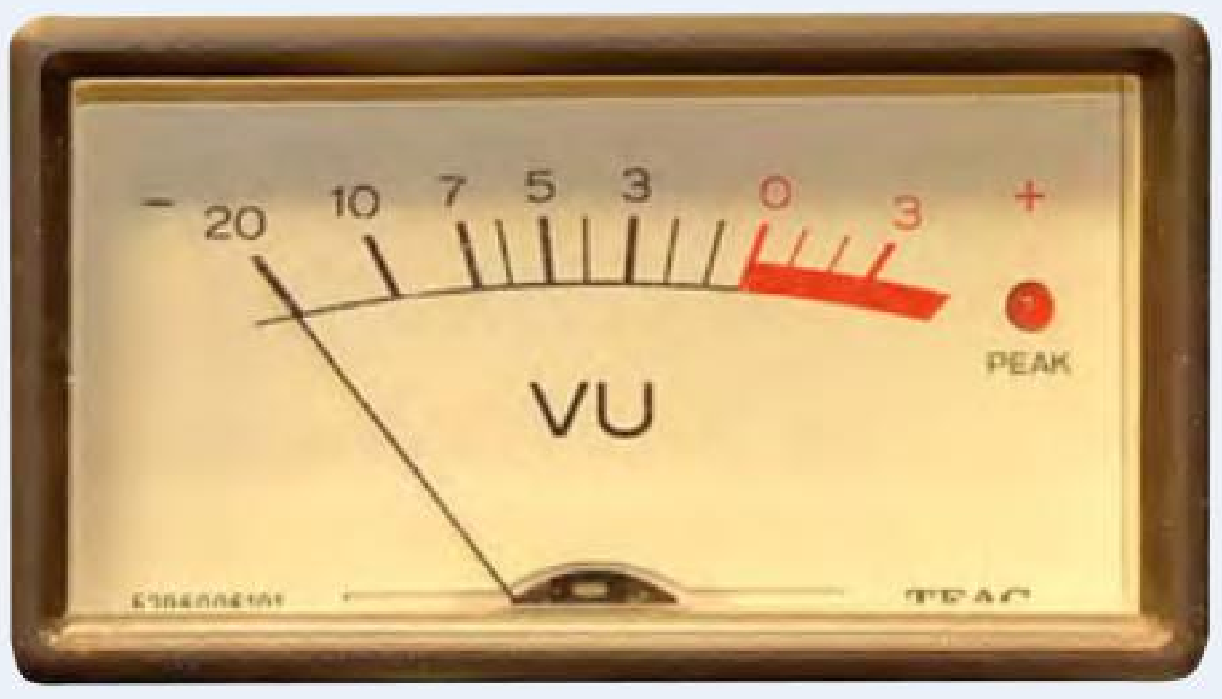
DIGITAL STEREO AUDIO LEVEL/VU METER

Fig.3: full circuit for the *Stereo VU Meter.* This shows the full 80-LED matrix at right, along with the power supply and details of the analogue circuitry. Dual Schottky diodes D2 and D3, in combination with the 22kΩ series resistors, protect IC2 from excessive input signal levels, while D4-D9 (with 1kΩ series resistors) prevent IC1's internal input clamp diodes


+3.3V
10Ω
100nF X7R
100nF X7R
100nF X7R
10k
LEFT CHANNEL
RIGHT CHANNEL
LED10
LED40
LED50
LED80
LED9
LED39
LED49
LED79
LED8
LED38
LED48
LED78
LED7
LED37
LED47
LED77
LED6
LED36
LED46
LED76
LED5
LED35
LED45
LED75
LED4
LED34
LED44
LED74
LED3
LED33
LED43
LED73
LED2
LED32
LED42
LED72
LED1
LED31
LED41
LED71
A
K
λ
17 AVDD
28 VDD
40 VDD
LS529 15 AN9/RB15/RPB15
LS23 21 AN2/RPB0/RB0/PGED1
LS1 19 AN0/VREF+/RA0
18 MCLR
5 A10 RPC9/PMA6/RC9
4 A9 RPC8/PMA5/RC8
3 A8 RPC7/PMA0/RC7
2 A7 RPC6/PMA1/RC6
38 A6 RPC5/PMA3/RC5
37 A5 RPC4/PMA4/RC4
36 A4 RPC3/RC3
27 A3 AN8/RPC2/RC2
26 A2 AN7/RPC1/RC1
25 A1 AN6/RPC0/RC0
RS529 14 AN10/RB14/RPB14
RS23 22 AN3/RPB1/RB1/PGEC1
RS1 20 AN1/VREFq/RA1
8 RB10/RPB10/PMD2/PGED2
9 RB11/RPB11/PMD1/PGEC2
ICSP
1
2
3
4
5
CON4
IC1
PIC32MX170
qF256D
TPBR
BR 11 AN11/RB13/RPB13
TPG1
S1
S2
23 K1 AN4/RPB2/RB2
24 K2 AN5/RPB3/RB3
33 K3 SOSCI/RPB4/RB4
41 K4 PGED3/RPB5/PMD7/RB5
42 K5 PGEC3/RPB6/PMD6/RB6
43 K6 RPB7/PMD5/RB7
44 K7 RPB8/PMD4/RB8
1 K8 RPB9/SDA1/PMD3/RB9
13 RA7/PMA7/TCK
12 RA10/PMA10/TMS/PGED4
10 RB12/PMD0/AN12
35 RA9/TDI/RPA9/PMA9
34 RA4/SOSCO/RPA4
32 RA8/TDO/RPA8/PMA8
31 RA3/OSC2/CLKO/RPA3
30 RA2/OSC1/CLKI/RPA2
7 VCAP
AVSS 16
VSS 6
VSS 29
VSS 39
10µF 6.3V X5R
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
D
G
S
D2qD9: BAT54S
1
2
3
REG2, IC2qIC4
8
4
1
LEDS
CATHODE BAND
K
A
Q1-Q8: 2N7002P
G
D
S
MCP1703T-3302E/DB
4 (GND)
(IN) 1
(GND) 2
3 (OUT)

from conducting, depending on the signal applied. Also shown in more detail on this diagram are the three different signal bias levels of 0V (GND), 1.65V (half supply for 3.3V) and 5.6V (half supply for 11.2V). The amplified and filtered input signals are fed to microcontroller IC1, which drives the LED bargraphs via MOSFETs Q1-Q8.

Simulating VU meter response



The adjacent photo shows an original VU meter. According to Wikipedia: 'The original VU meter is a passive electromechanical device, namely a 200µA DC d'Arsonval movement ammeter fed from a full-wave copper-oxide rectifier mounted within the meter case. The mass of the needle causes a relatively slow response, which in effect integrates the signal, with a rise time of 300ms. 0 VU is equal to +4dBu, or 1.228V RMS across a 600-ohm load...'

This Stereo LED VU Meter does not attempt to exactly replicate the operation of a VU meter. For example, the copper-oxide rectifier causes a VU meter to be inaccurate for low-level signals and thus makes a reading below –20dB difficult. We're still using proper RMS calculations and showing readings on a range of at least 40dB (depending on the range setting of the unit).

However, we have been able to implement a simulation of the ballistic properties of the VU meter needle in our software. When a 1kHz sinewave is applied to a standard VU meter which had previously had no signal applied, it should reach 99% of the final reading in 300ms and have an ultimate overshoot of between 1% and 1.5% of the reading. We've achieved this with a simple needle inertia simulation that tracks the needle position and velocity along with a target position (based on the current RMS reading), an acceleration coefficient and a damping coefficient. These two coefficients were tuned to achieve the required response, as stated above.

socket CON3, or else wired directly between TPV+ and TPG1.

Schottky diode D1 provides reverse polarity protection and drops less than 0.4V. The 11.6-14.6V DC at its cathode is fed to two resistors. One is a 33Ω 1W SMD type which connects to the input of 3.3V low-drop-out (LDO) regulator REG1. This is in a relatively large SOT-223 4-pin package that is soldered to a considerable copper area, which includes thermal vias to conduct heat to the back of the board.

With a 14.5V input, 3.3V output and maximum load of 125mA, these components dissipate (14.5V – 3.3V) × 0.125A = 1.4W. Around 0.5W will be dissipated in the resistor with the remaining 0.9W in the regulator, hence the copper plane heatsinking on both sides, along with thermal vias under the regulator package.

SMD multi-layer ceramic capacitors are used to bypass the input and filter the output of REG1. As well as supplying the microcontroller and LEDs, the 3.3V output flows through a pair of series-connected 3.9kΩ resistors to generate the 1.65V rail, which is bypassed with a 47µF capacitor. This is important because the varying current demand on the 3.3V rail as LEDs are switched causes ripple, and we don't want this to couple into the input signal path.

The 11.6-14.6V at the cathode of D1 also flows to adjustable low-dropout regulator REG2 (MIC5201). The 10Ω series resistor forms a low-pass filter in combination with its 2.2µF input bypass capacitor to reduce the amount of ripple reaching REG2. It also causes a voltage drop of up to 0.25V.

REG2's output is set at 11.15V (nominal) by the 12kΩ and 1.5kΩ resistors. REG2's minimum input voltage is around 11.6V – 0.25V = 11.35V. With a load current of only 25mA, REG2's dropout voltage is less than 150mV, so it should stay in regulation. This is important since REG2 exists to eliminate ripple on the op amp supplies; even with a 100dB CMRR (common-mode rejection ratio), several hundred millivolts of ripple can have a significant impact on the overall signal-to-noise ratio of the system.

The 5.6V half-supply reference for the op amps is derived from the 11.2V supply with a 1kΩ resistor and 5.6V zener diode ZD1, which is bypassed with another 47µF capacitor. This further attenuates any ripple which may make it through the regulator.

Microcontroller IC1 has three 100nF ceramic supply bypass capacitors, with its AVCC supply filtered by one of these in combination with a 10Ω series resistor. A 10µF ceramic capacitor between pin 7 (VCAP) and ground provides an output filter for its internal 2.5V core regulator, while a 10kΩ pull-up between the 3.3V rail and pin 18 ($\overline{\text{MCLR}}$) prevents spurious resets.

PCB layout

The PCB design is crucially important to achieve the desired performance level. The relatively compact PCB means that the switched LED supply lines inevitably run somewhat near the front end and the tiny amount of signal that couples in is picked up and amplified by the op amps. This is mostly ignored by the software (as explained later) but it does make the noise level in the left channel slightly worse than the right (but still below –100dB) due to its greater proximity to the LEDs.

The most critical part of the layout is the ground track routing. While all points connected to ground in the circuit must be joined together, there are a large number of ways this could be achieved, many of which would cause digitally switched currents to cause voltage shifts across different parts of the analogue front-end, ruining the performance.

The grounds for input sockets CON1 and CON2, regulators REG1 and REG2 (and their output filter capacitors but NOT input bypass capacitors) and the bottom end of the two half-rail bias generators are connected together, then brought back to pin 16 of IC1 (AGND). This pin is also used as the negative reference voltage for the ADC. This routing means that the analogue grounds and half-supply rails have very little AC voltage between them, as little current flows through these tracks and that which does is linearly proportional to the input signal.

AGND is connected to GND within IC1, and also by tracks running under it, so ultimately these pins all connect to GND. The op amp negative supply pins and their bypass capacitors are connected back to the ground pin of REG2 and the more-or-less constant supply current flows from there back to AGND and on to the main ground network.

Firmware operation

While the software is conceptually simple, it has quite a few modes and features. Its three main tasks are to continually sample the analogue inputs, perform the average and peak calculations based on the results and drive the multiplexed LED display. The first and last are 'real time' tasks so they are interrupt driven, with priority given to the LED multiplexing, as any delays could cause the display to flicker.

The LED multiplexing is achieved using three of the five 16-bit timers internal to IC1: Timer1, Timer2 and Timer3. IC1 runs at 40MHz, in order to perform the required calculations fast enough to provide a rapid display update (around 40 updates per second). Timer1 is set up to trigger an interrupt every 65,536 (2^{16}) clock cycles, ie, every 65,536 ÷ 40MHz = 1.6384ms. Since there are eight cathodes to cycle through, this gives a display refresh rate of 76Hz.

When this interrupt is triggered, the code branches to the Timer1 interrupt handler, which switches the LED anode drive outputs (RC0-RC11) low, then cycles the next MOSFET drive output (RB2-RB9) high. It then calculates which anodes to drive to light the appropriate LEDs and brings some combination of RC0-RC11 high.

If the brightness trimpot is set at a level below 100%, before the interrupt handler completes, it enables Timer3 and sets it for a value proportional to the brightness. When the interrupt handler for Timer 3 is subsequently triggered, RC0-RC11 are brought low, cutting off the LED drive to reduce the average display brightness. Both interrupt priorities are set to level four, the highest used.

An error in the silicon?

This multiplexing method works very well, giving a stable and bright display. At least, it did until we enabled the ADC. Even with ADC interrupts disabled, it caused the LED display to flicker.

We couldn't understand why, since the timer period should not be affected by the operation of the ADC and the flickering occurred even without enabling interrupts for the ADC unit at any location in the code. So why should the ADC interfere with the multiplexing?

We got a clue by examining the MOSFET drive signals for Q1-Q8 using an oscilloscope. Periodically, one of the MOSFET gate drive pulses would be extremely short; rather than the expected 1.6384ms, it measured something like 50µs, appearing as just a spike on the screen. Following that occurrence, the next pulse for that same MOSFET would occur about 11.5ms later, or roughly seven timer periods, rather than the expected 13.1ms (eight timer periods).

This pointed to the possibility that, having completed the Timer1 interrupt handler, the processor would sometimes immediately re-enter it and thus the code would then assume some time had passed and switch to the next multiplexed bank of LEDs prematurely. For some reason, this occurred only when the ADC was enabled and active. We can't figure out how the software caused this, since when the ADC is in auto-sampling mode, with interrupts disabled, it operates autonomously.

Parts List

- 1 double-sided PCB, available from the *EPE PCB Service*, coded 01104161, 177 × 75.5mm
- 1 white switched PCB-mount RCA socket (CON1)
- 1 red switched PCB-mount RCA socket (CON2)
- 1 PCB-mount switched DC socket, 2.1 or 2.5mm inner diameter (CON3)
- 1 5-pin header, 2.54mm pitch (optional, to program IC1) (CON4)
- 2 PCB-mount mini tactile switches (S1,S2)
- 1 10kΩ SMD trimpot, TC33X type (VR1)
- 5 PC stakes (optional; see text)
- 1 12-15V DC 150mA+ power supply

Semiconductors

- 1 PIC32MX150F128D-I/PT or PIC32MX170F256D-I/PT 32-bit microcontroller programmed with 0110416A.hex, TQFP-44 (IC1)
- 3 NE5532D dual low-noise op amps, SOIC-8 (IC2-IC4)
- 1 MCP1703-3302E 16V in, 3.3V out, 250mA low-dropout regulator, SOT-223 (REG1)
- 1 MIC5201YM 20V, 200mA adjustable low-dropout regulator, SOIC-8 (REG2)
- 8 2N7002P logic-level N-channel MOSFETs, SOT-23 (Q1-Q8)
- 1 BZX84C5V6 5.6V 1/4W zener diode, SOT-23 (ZD1)
- 1 30V 1A Schottky diode, SMA/DO-214AC or Mini2 SMD package (D1)
- 8 BAT54S dual series Schottky diodes, SOT-23 (D2-D9)
- 60 high-brightness green SMD 3216/1206 LEDs (LED1-30, LED41-70)
- 8 high-brightness yellow SMD 3216/1206 LEDs (LED31-34, LED71-74)
- 8 high-brightness amber SMD 3216/1206 LEDs (LED35-38, LED75-78)
- 4 high-brightness red SMD 3216/1206 LEDs (LED39-40,LED79-80)
- 8 high-brightness blue SMD 3216/1206 LEDs (LED81-88)

Capacitors (SMD 2012/0805 unless specified)

- 2 47µF 6.3V X5R 2012/0805 or 3216/1206
- 2 10µF 6.3V X5R 2012/0805 or 3216/1206
- 11 2.2µF 16V X5R
- 6 100nF 50V X7R
- 2 1nF 50V C0G
- 2 680pF 50V C0G
- 6 100pF 50V C0G

Resistors (SMD 2012/0805, 1% 0.125W unless specified)

- 2 22kΩ or 22.1kΩ 1% 0.5W 3216/1206
- 14 22kΩ
- 2 20kΩ
- 1 12kΩ
- 1 10kΩ
- 1 33Ω 5% 1W 6331/2512
- 2 10Ω
- 4 3.9kΩ
- 1 1.5kΩ
- 19 1kΩ

Optional parts

Tapped spacers and M3 machine screws for mounting, shielded cable and twin-lead for hard wiring, case with clear lid

Optional laser-cut case

- 1 set 3mm clear acrylic pieces
- 1 small tube acrylic glue (solvent-based)
- 4 M3 × 10mm machine screws
- 2 M3 × 12mm tapped Nylon spacers
- 4 M3 shakeproof washers

Where to buy parts

The PCB, programmed microcontroller, case pieces and red/white RCA sockets are available separately from the SILICON CHIP Online Shop. We're also offering a set of parts containing all the SMDs except for the microcontroller and LEDs. Sets of 10 red, amber, yellow, green or blue high-brightness 3216-size SMD LEDs with diffused lenses are available separately, so that constructors can choose their own colours.

Handling higher amplitude signals

As presented, the circuit is designed to accept sinewave signals up to 2.33V RMS (6.6V peak-to-peak or 3.3V peak). Signals above this level will cause D2 and D3 to conduct and the meter will simply show a full-scale reading but no damage should occur.

This is not sufficient to monitor the outputs of a power amplifier. Some equipment may also produce line-level signals above 2.33V RMS. In this case, it's simply a matter of changing the input divider so that, with the maximum input signal level, the resulting voltage does not exceed 3.3V peak-to-peak. The parallel combination of the two divider resistors should be kept to 11kΩ. This means that the 'lower' leg resistor will need to be reduced in value, probably to somewhere in the range of 11-15kΩ.

Consider a power amplifier which can deliver 135W into 8Ω or 200W into 4Ω. This requires an output voltage of √(135 × 8) = 33V RMS or 93V peak-to-peak (33V × 2.828). For 200W into 4Ω, the output will be √(200 × 4) = 28.3V RMS. So the meter would need to handle 33V RMS to monitor the outputs directly.

This means a divider ratio of at least 93V ÷ 3.3V = 28.2 is required. We set the bottom leg to 11kΩ (ie, the resistor from the 5.6V rail) since the other resistor value will be much larger and have negligible contribution to the divider's output impedance. The other resistor will then need to be at least 11kΩ × (28.2 – 1) = 300kΩ. This happens to be an E24 value; if it wasn't, we would have chosen the next higher value. The parallel resistance is 1 ÷ [(1 ÷ 11kΩ) + (1 ÷ 300kΩ)] = 10.6kΩ, which is close enough to 11kΩ.

This new divider reduces the input levels by 23dB compared to the original design, so the +7dBV setting is in reality now +30dBV, which would indicate full amplifier power into 8Ω. Note that the other reference levels will be effectively increased by the same amount.

Simple solution

In the end, we came up with a simple solution: we set Timer2 to the same time base and period as Timer1. When the Timer1 interrupt handler is about to exit, it resets Timer2. At the start of the Timer1 interrupt handler, we check the value of the Timer2 counter. If it's less than half the expected value, indicating that the Timer1 interrupt should not have occurred yet, we exit the interrupt handler without doing anything. This allows us to ignore the occasional spurious event.

Our guess as to the nature of this problem is that an implementation bug in this series of PIC32s causes some interrupt handlers to be re-triggered upon exit if something else is going on in the chip simultaneously.

A 'gotcha'

Another issue we ran into is that the display also started flickering when we added the code to update the states of LEDs81-88. Unlike the previous issue, this turned out to be our fault. LED86 is driven by output RB12 which is on the same port as the pins driving MOSFETs Q1-Q8 (ie, RB2-RB9). The code to update the state of LED86 read:

```
LATBbits.LATB12 = !(Sensitivity == 1);
```

This looks like an atomic operation, setting the bit LATB12 which controls the state of output RB12. However, it is actually a read-modify-write operation, ie, the value of special register LATB is transferred to a general-purpose register, the value of bit 12 is changed and the result is then transferred back to the special register.

But if the Timer1 interrupt handler is triggered in the middle of this procedure, it may change the value of special register LATB. When the special register is written back later by the above code, that overrides the change made by the interrupt handler.

One possible solution is to temporarily disable interrupts while updating LATB12, but that's clumsy. The elegant solution is to take advantage of the special set/clear/toggle registers available for all the GPIO registers (and many others) on this chip, ie:

```
if( Sensitivity == 1 )
    LATBCLR = 1<<12;
else
    LATBSET = 1<<12;
```

These operations are atomic, ie, can't be interrupted. If an interrupt handler is triggered simultaneously, it will be executed either before or after the clear/set operation, eliminating the flicker.

Analogue computations

The input signals (left and right channels) are applied to six different analogue inputs: two with an overall gain of one half, two with a gain of 11.5 times and two with a gain of 264.5 times. However, rather than switch between sampling these different inputs depending on signal level, we simply sample all six, all the time. The code in the ADC conversion complete interrupt handler routine decides which to use, depending on the values returned.

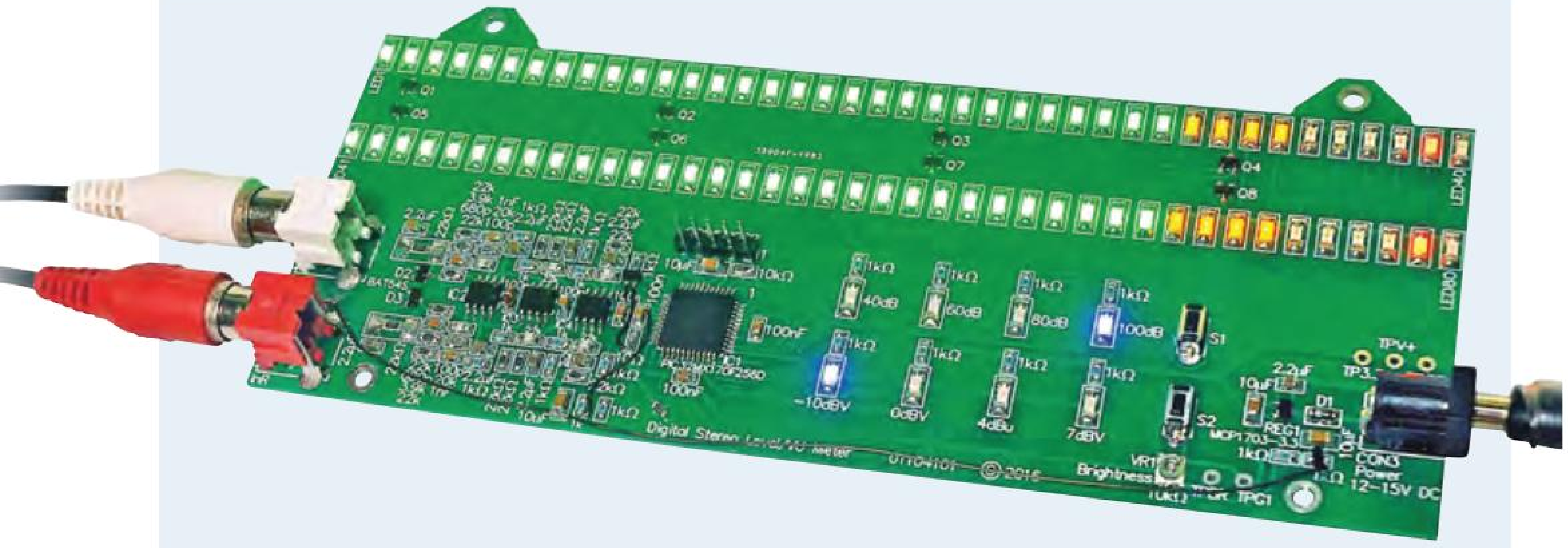
If the value from the input amplified by 264.5 times is very near either rail (ie, the conversion result is very close to either zero or 1023), the value from the 11.5 times amplified input is used instead, multiplied by 23 so that it has the same scale as readings from the other input. If that lower-gain input is also found to be very near either rail, the value from the third, attenuated input is kept instead, multiplied by 529 (23 × 23). The result is then stored in one of two 1024-entry stereo buffers for later analysis, to keep the interrupt handler routine quick so it won't interfere with LED multiplexing.

The micro's peripheral clock is set to run at half the rate of the main clock, ie, 20MHz. The ADC clock input divider is set to a factor of two, giving 10MHz. Each conversion takes 12 cycles, plus eight cycles for the sample-and-hold buffer to stabilise, for a total of 20 cycles each (10MHz ÷ [20 × 6] = 83.3kHz). We average each pair of sample values to reduce system noise, resulting in a final sampling rate of 41.6kHz, sufficient for measuring signal frequencies up to 20.8kHz (the Nyquist limit).

Once a sample buffer is full, the code's main loop calculates the average of all values and subtracts it from the sample values to remove any DC offset or low-frequency signals which have not been rejected by the analogue filter. It then computes the RMS and peak values for each channel.

The resulting RMS values are then stored and averaged over a configurable number of 1024-sample intervals, so that it varies smoothly. Similarly, the highest peak values across multiple 1024-sample buffers are computed.

These RMS and peak values are converted into decibels using a logarithmic calculation, taking into account the current range and reference level selection. The display is then updated to show the peak and/or average results (depending on the display mode).



We used green, yellow, amber and red LEDs in the bargraphs, but you can change these to suit your requirements. Part 2 next month has the assembly details. Note: prototype board shown.

Other functions

Button presses are sensed using a pin change interrupt and debounced using Timer4 (S1) or Timer5 (S2). When a press is detected, the interrupt handler sets a flag and the main loop updates the mode and then saves the new setting to flash memory. These saved settings are automatically loaded each time the unit is powered up.

Long presses (>0.5s) have a different effect compared to short presses and this is determined by when the associated timer rolls over. As well as using these buttons to change the display range and reference level, various combinations can be used to change settings, to be described next month in Part 2.

Noise nulling is implemented by storing the left and right channel RMS and peak values when S1 is held down, both in RAM and flash memory. These are subtracted from subsequent readings, with the RMS noise figure being subtracted in an RMS manner.

LED colours

In our prototype, we used 30 green LEDs at the left end of each bargraph, followed by four yellow, four amber and two red. This is a purely aesthetic choice. You could make them all the same colour (eg, blue), or use a different combination than we did.

While brightness matching between different colours is generally good enough, the software allows you to provide some drive compensation to reduce the difference in apparent brightness between different colour LEDs.

We also decided to make LEDs81-88 blue, in contrast to LEDs1-80 and the parts list reflects our choices.

That's all we have space for this month. Next month we'll get onto the PCB construction, testing, operation and fitting the unit into a case.

Laser
Why tolerate when you can automate?

X-10 Home Automation

KAT5 AV transmission and IR control system

Barix Ethernet based MP3, communications and control systems

www.laser.com

Integrators, Installers, Trade and Retail customers welcome

C-Bus Shop
C-Bus and C-Bus Wireless
www.cbus-shop.com

Laser Business Systems Ltd
Tel: +44 (0) 20 8441 9788
Fax: +44 (0) 20 8449 0430
Email: info@laser.com
16 Garthland Drive, EN5 3BB

PoLabs

For more information or software download please visit

www.poscope.com/epe

PoKeys
Connect, Control

- USB
- Ethernet
- Web server
- Modbus
- CNC (Mach3/4)
- IO
- PWM
- Encoders
- LCD
- Analog inputs
- Compact PLC

Stepper motor drivers
Drive

- up to 256 microsteps
- 50 V / 6 A
- USB configuration
- Isolated
- up to 32 microsteps
- 30 V / 2.5 A

PoScope Mega1+
PoScope Mega50
Measure

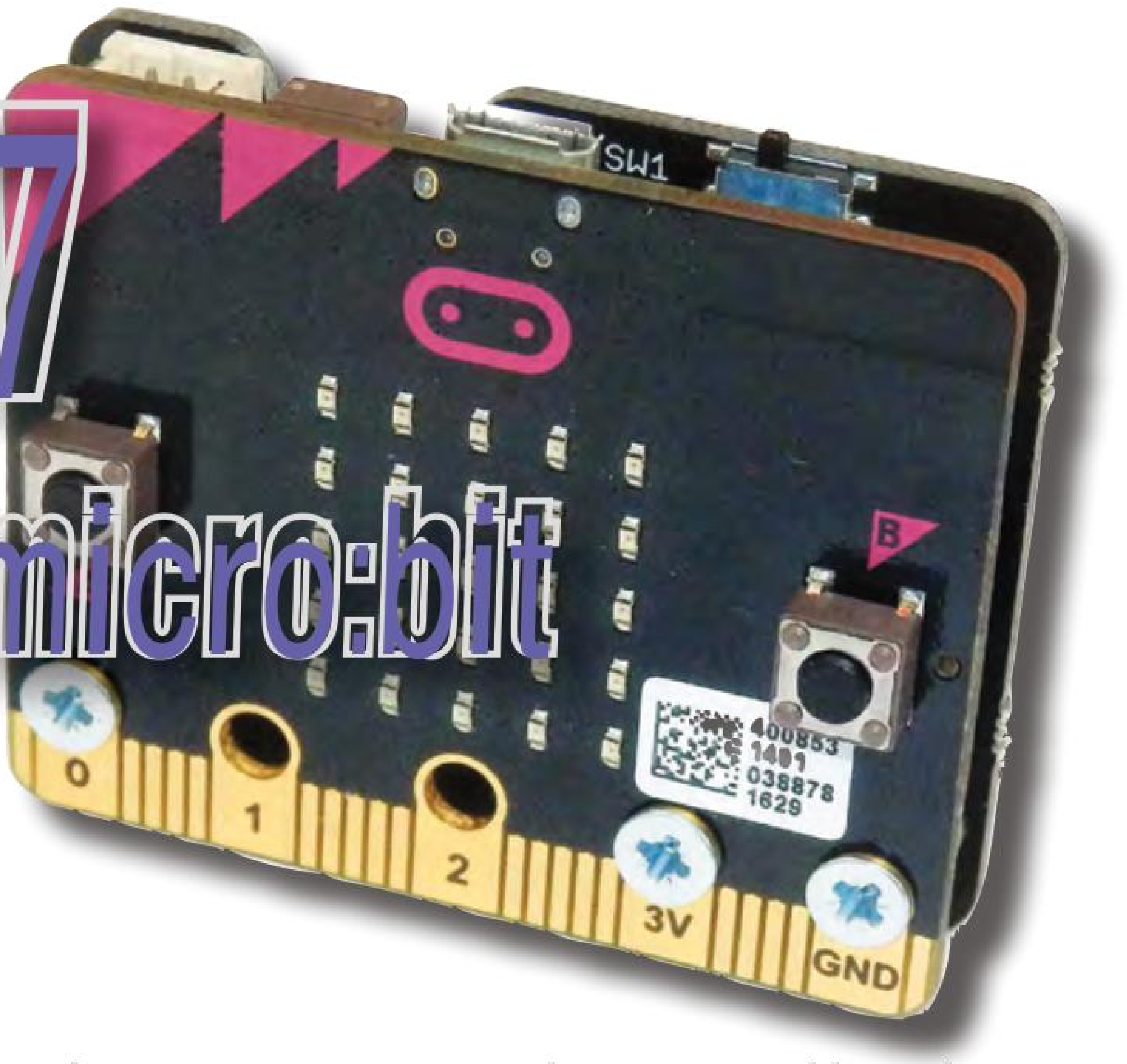
- up to 50MS/s
- resolution up to 12bit
- Lowest power consumption
- Smallest and lightest
- 7 in 1: Oscilloscope, FFT, X/Y, Recorder, Logic Analyzer, Protocol decoder, Signal generator

Teach-In 2017

Introducing the BBC micro:bit

Part 1: Meet the micro:bit

by Mike Tooley


SW1
B
400853
1491
038878
1629
0
1
2
3V
GND

Welcome to *Teach-In 2017 – Introducing the BBC micro:bit*. Following on from our popular *Teach-In 2016* series on the Arduino (and previously the Raspberry Pi), Mike Tooley has extended his investigation of low-cost microcontrollers to the recently introduced BBC micro:bit. Not just an educational resource for teaching kids coding, this tiny low-cost microcontroller provides you with yet another solution to the problem of controlling a wide range of electronic projects, ranging from simple domestic gadgets to more complex control systems such as those used for lighting, central heating and security applications.

To get you up and running quickly, each *Teach-In 2017* article will conclude with a simple but useful practical project. In this first part, Mike introduces the board, explains the hardware and shows you how to get started with coding. Our practical project takes the form of a simple electronic compass.

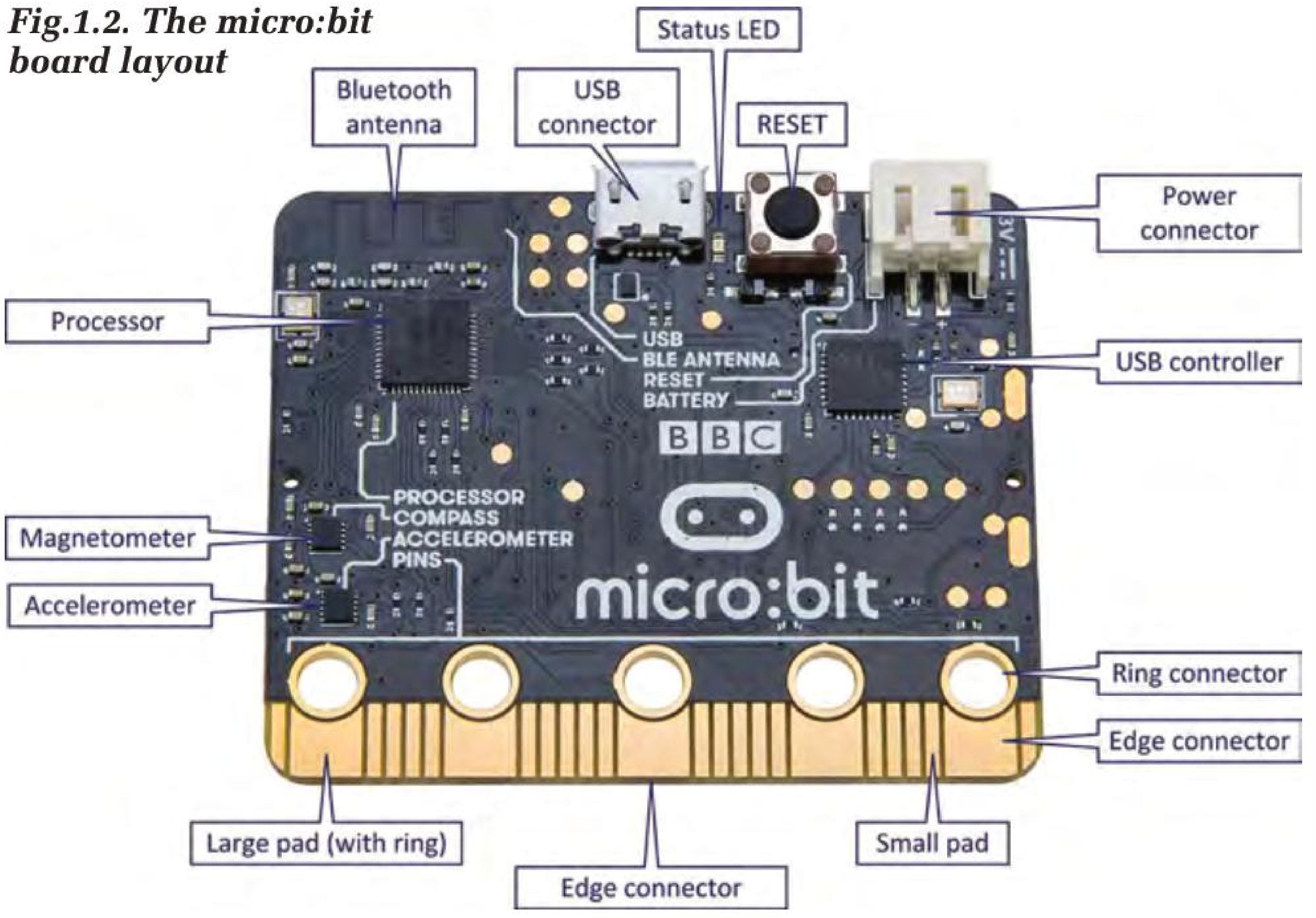
Introducing the BBC micro:bit

Originally intended as a learning resource for students in UK secondary schools, the BBC micro:bit is a tiny low-cost, low-profile ARM-based single-board computer. The board measures a mere 43mm × 52mm. However, despite its diminutive footprint the board has all of the features of a fully-fledged microcontroller, together with a rudimentary but nonetheless functional 5 × 5 LED matrix display, two buttons and various sensors, including an accelerometer and a magnetometer. The board can be powered and programmed via a USB cable or derive its power from an external 3V DC supply (usually two AAA batteries). In addition, there is an on-board Bluetooth low-energy (BLE) interface for short-range wireless applications.

The BBC micro:bit can be purchased singly or supplied as part of an introductory 'kit' comprising a micro:bit, USB lead, battery holder, and two AAA cells. There are significant discounts for purchasing 'class sets' of boards for use in educational establishments, making the board competitive with alternative solutions such as the Arduino Uno and Raspberry Pi.

The layout of the main components is shown in Fig.1.2. One edge of the board comprises a somewhat unorthodox edge connector, which rather cleverly combines pads on a 0.05-inch (1.27mm) pitch with the five larger pads and

Fig.1.2. The micro:bit board layout


Status LED
Bluetooth antenna
USB connector
RESET
Power connector
Processor
USB controller
USB
BLE ANTENNA
RESET
BATTERY
BBC
PROCESSOR
COMPASS
ACCELEROMETER
PINS
micro:bit
3V
Magnetometer
Accelerometer
Ring connector
Edge connector
Large pad (with ring)
Small pad
Edge connector

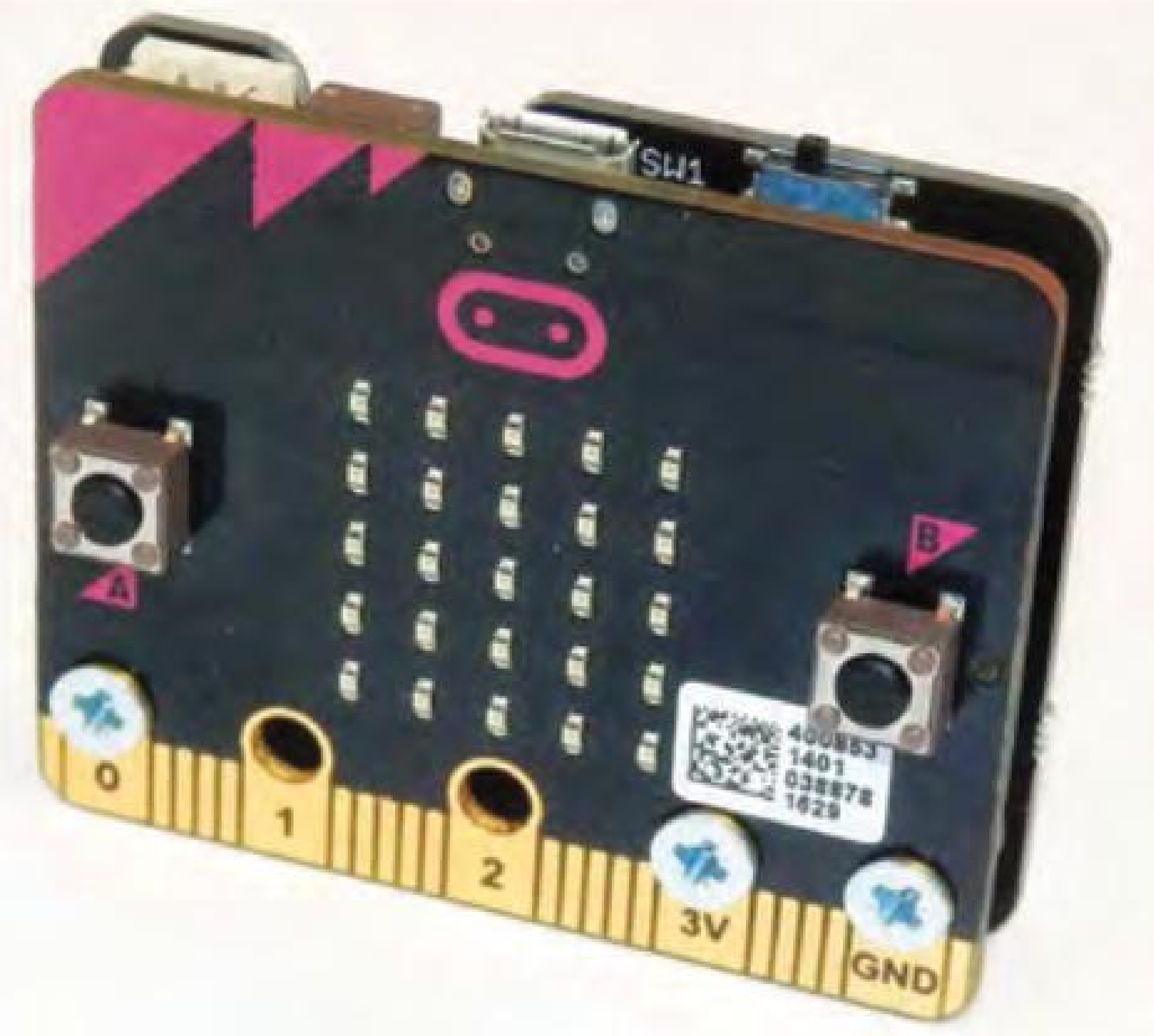

SW1
A
B
0
1
2
3V
GND

Fig.1.1. The BBC micro:bit with MI:power board attached

Table 1.1 Specifications

Processor	32-bit Nordic Semiconductor nRF51822
Regulator/USB controller	NXP/Freescale KL26Z
Processor clock speed	16MHz (32.768kHz switchable)
Memory	256KB Flash and 16KB static RAM
Wireless	2.4 GHz Bluetooth low energy (BLE)
Accelerometer	3-axis accelerometer sensor via I²C-bus
Magnetometer	3-axis magnetometer sensor via I²C-bus
Edge-connector	23-pin 0.05-inch (1.27mm) pitch (see text)
Display	25 red LEDs in a 5×5 matrix
Inputs	2 user buttons (plus RESET)
DC supply	5V nominal (via USB) or 3.3V battery
Dimensions	43mm × 52mm

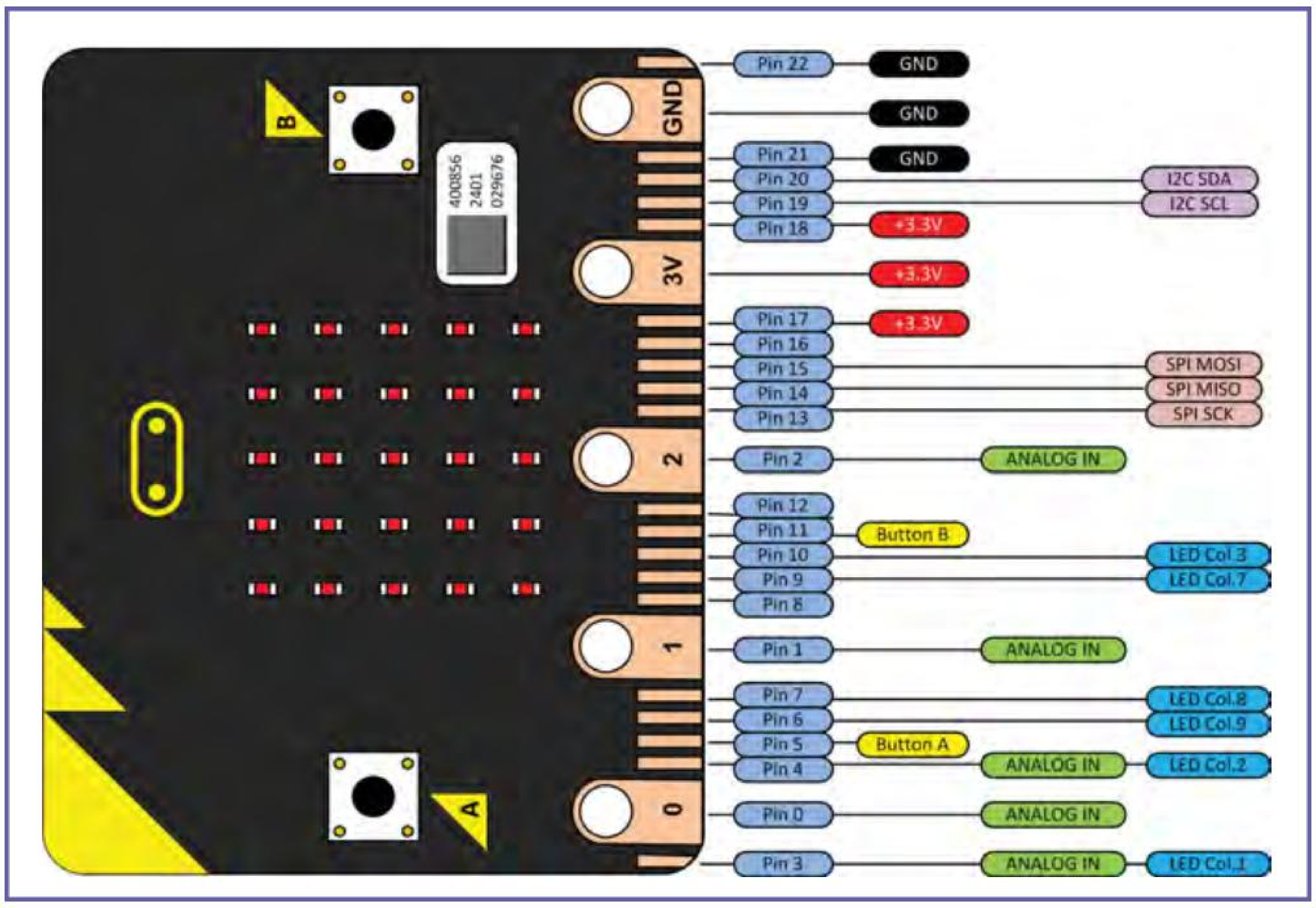


Fig.1.3. The edge connector pin assignment

rings intended for use with crocodile clips and 4mm banana plugs respectively.

Specifications

The processor is a tiny 32-bit nRF51822 (ARM Cortex M0) from Nordic Semiconductor. This is a powerful reduced instruction set (RISC) machine designed specifically for energy and space-efficient applications. The processor has 256KB Flash memory and 16KB of static ram. The ARM core can switch between 16MHz and 32.768kHz.

The processor is supported by an NXP/Freescale KL26Z. This 48MHz device relieves the processor from the burden of communication by providing a full-speed USB 2.0 on-the-go (OTG) interface for external devices. The KL26Z also provides the voltage regulation from the USB supply, converting the nominal 5V USB supply to a nominal 3.3V for the processor and other support devices. This supply is also made available at the edge connector. The abbreviated specifications are shown in Table 1.1.

On-board sensors and interfaces

A variety of useful sensors and interfaces are provided on-board. These include a 3-axis magnetometer and a 3-axis accelerometer, plus light and temperature sensors. For communication and interfacing, the board is provided with Universal Serial Bus (USB), universal asynchronous receiver/transmitter (UART), Serial Peripheral Interface (SPI), and Inter-integrated Circuit Interface (I^2C) facilities.

The edge connector

The 24-pin connector along the lower edge of the board provides access to the micro:bit's input and output signals, as well as the two buttons (A and B), power and ground. Five of the pads have been enlarged, in order to facilitate crocodile clip connection and banana plugs. These pads also have large plated-through holes to accommodate standard 4mm plugs. Note that the numbering is not strictly sequential and the large supply (3.3V) and ground (GND) pins are not numbered at all.

The edge connector pin assignment is shown in Fig.1.3. Several pins have multiple functions. The default function of each pin is shown in Table 1.2.

Although several of the pads have been enlarged to make connection easier, it is essential to use an edge connector if you do need to connect to the full set of edge connector signals. Fortunately, several suppliers have responded to this need and can supply boards fitted with edge connectors specifically designed to accommodate the micro:bit. Some of these boards also have terminal blocks for solderless connection to external devices as well as built-in supply regulators, which facilitate the use of an external unregulated external DC supply of up to 12V (see Fig.1.4).

I/O signals

micro:bit I/O signals can be grouped by their function:

- General purpose I/O (GPIO)
- Analogue input
- LED column
- Button (A or B)
- Pulse-width modulation (analogue output)
- Serial asynchronous communication (UART)
- Serial peripheral interface bus (SPI)
- Inter-integrated circuit bus (I^2C).

Table 1.2 Default functions associated the I/O pins

Pin	Function	Use
0	GPIO	Large pad for general purpose digital I/O, analogue input and PWM
1	GPIO	Large pad for general purpose digital I/O, analogue input and PWM
2	GPIO	Large pad for general purpose digital I/O, analogue input and PWM
3	LED Col. 1	Can be used as GPIO etc. when the LED display is not being used
4	LED Col. 1	Can be used as GPIO etc. when the LED display is not being used
5	Button A	GPIO etc. shared with Button A
6	LED Col. 9	Can be used as GPIO etc. when LED display is not being used
7	LED Col. 8	Can be used as GPIO etc. when LED display is not being used
8	GPIO	General purpose digital I/O, analogue input and PWM output
9	LED Col. 7	Can be used as GPIO etc. when LED display is not being used
10	LED Col. 3	Can be used as GPIO etc. when LED display is not being used
11	Button B	GPIO etc. shared with Button B
12	GPIO	GPIO etc. (see Note 1)
13	GPIO	GPIO etc. (also SCLK for SPI bus applications)
14	GPIO	GPIO etc. (also MISO for SPI bus applications)
15	GPIO	GPIO etc. (also MOSI for SPI bus applications)
16	GPIO	General purpose I/O, PWM and UART
17	3.3V	+3.3V (positive supply and linked to the adjacent pad marked '3V')
18	3.3V	+3.3V (positive supply and linked to the adjacent pad marked '3V')
19	I^2C SCL	Serial clock for the I^2C bus (also available as GPIO etc.)
20	I^2C SDA	Serial data available for the I^2C bus (also available as GPIO etc.)
21	GND	Ground (common negative supply, linked to adjacent pad marked 'GND')

Notes

1. Pins 3, 4, 6, 7, 9 and 10 are associated with the matrix LED display and also with the micro:bit's ambient light sensing mode.
2. Pins 5 and 11 are associated with the two on-board buttons (A and B respectively).
3. Although pin 12 is currently available for general purposes, it should be considered as 'reserved for future use'. Future versions of the micro:bit may use this pin for a dedicated purpose.
4. Pins 19 and 20 are used by the I^2C bus. This bus is used by the on-board accelerometer and magnetometer chips and care should be taken if you intend to use these pins for any other functions.

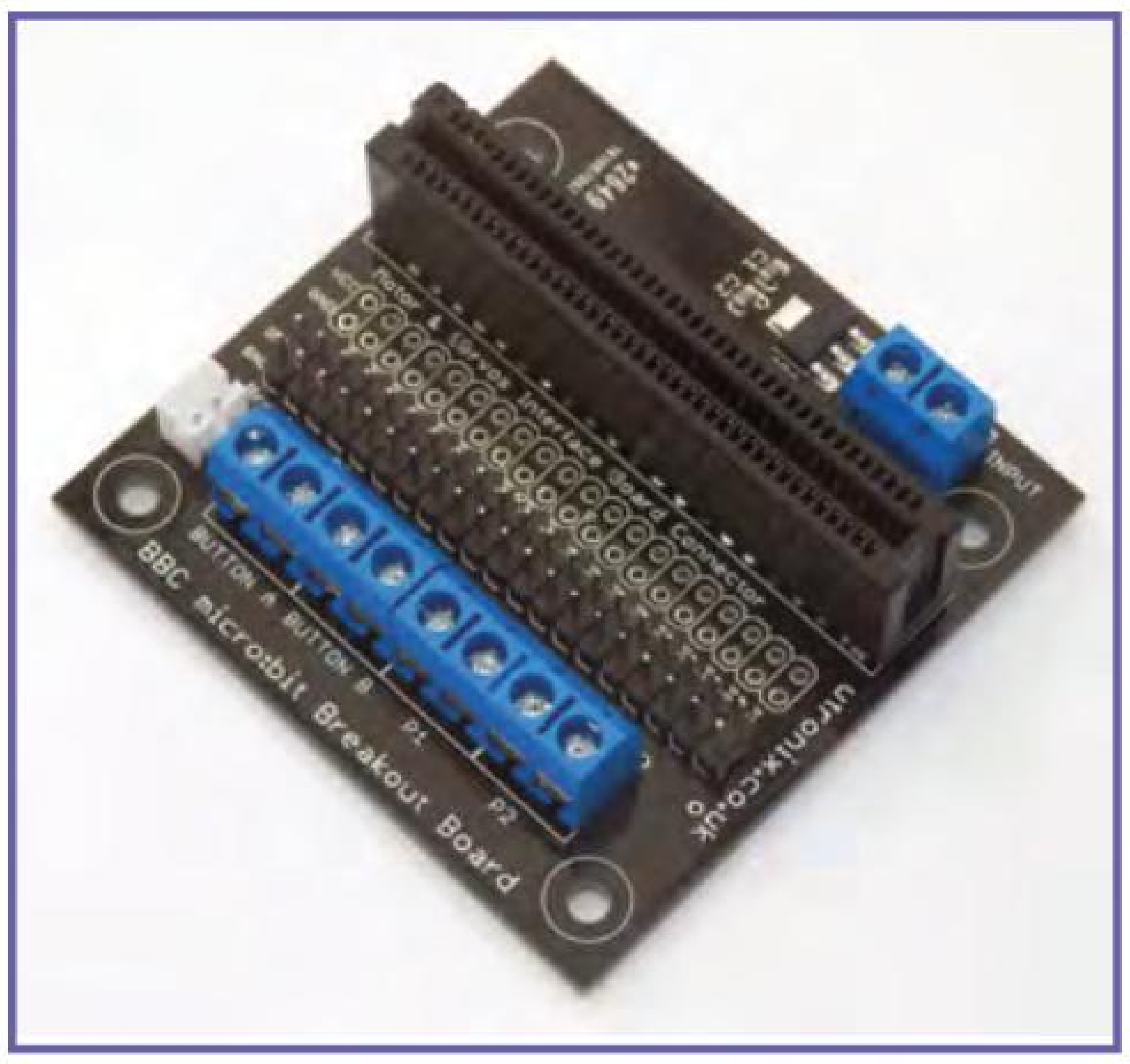


Fig.1.4. A micro:bit expansion board with terminal block connectors

Note that to use signals within some of these function groupings (see Table 1.2) it may be necessary to disable the default functionality for the pin concerned. We will explain how this is done in a later instalment.

Using buttons to replicate external inputs

The functions of the two buttons (labelled A and B) are respectively duplicated on pin-5 and pin-11 of the edge connector. This simply means that, if pin-5 is taken low (ie, connected to GND) it has the same effect as pressing button A. Similarly, if pin-11 is taken low, this will have the same effect as pressing button B. This feature can be quite handy as it will allow you to use a button press to simulate the signal from a switch or external digital sensor without having the device physically present and connected to the micro:bit.

Status LED

The status LED becomes illuminated whenever the micro:bit is connected to the USB port of a powered host computer, and flashes when data is being downloaded. The status LED will also be illuminated when the micro:bit is being powered from a USB power adapter. Note there is NO power indication when the LED matrix display is not being used and the micro:bit is deriving its power from a local battery.

Batteries and holders

The BBC micro:bit is designed to operate from a 3.3V DC supply. In practice, this can range from around 1.8V to 3.6V, but we would recommend using two alkaline AAA batteries for most applications. If you need to run your micro:bit continuously then a better solutions might be to use two AA batteries or make use of a 5V USB supply where mains voltage is available. The DC supply should never be allowed to exceed 3.8V as this may result in damage to the board.

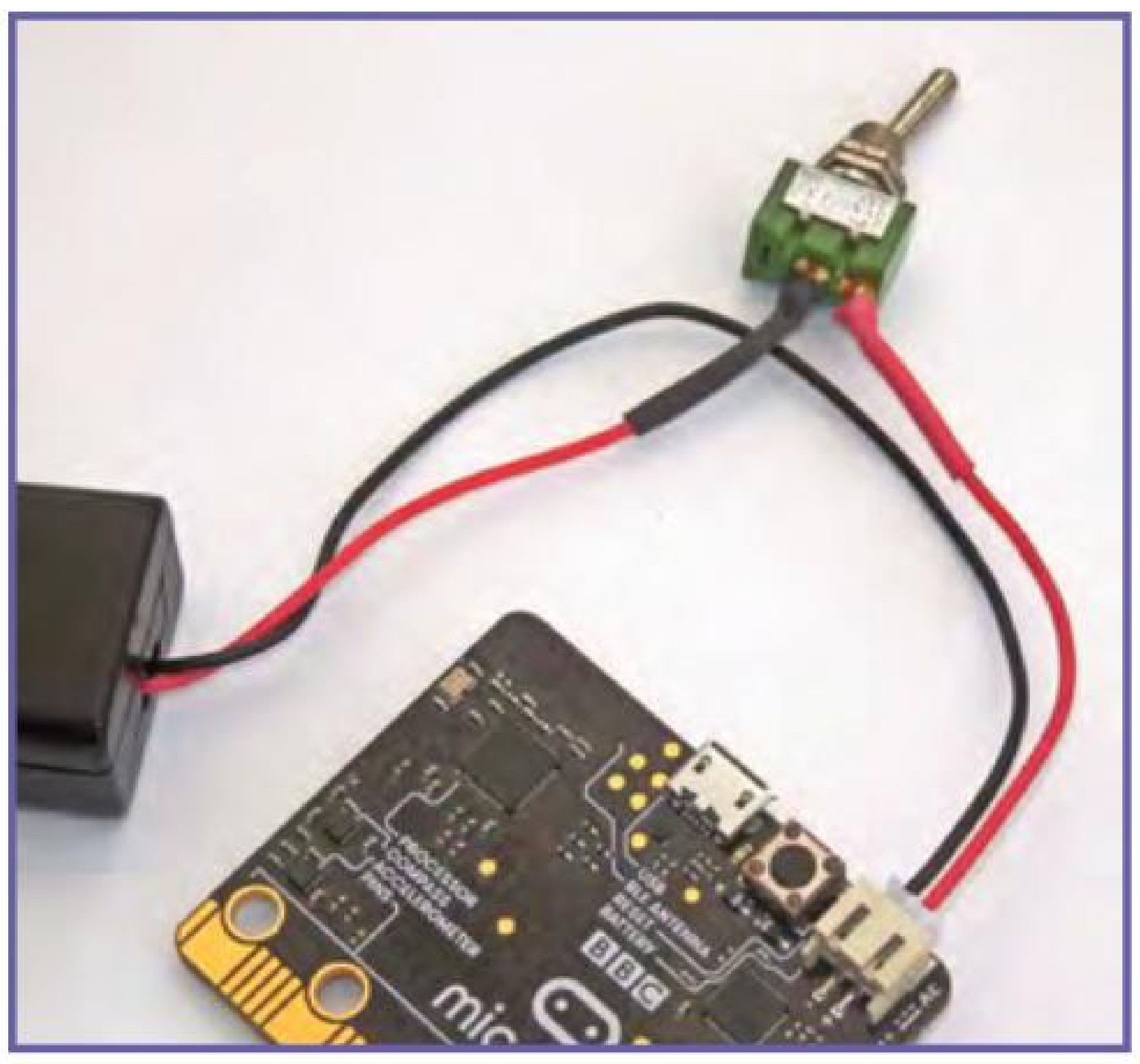


Fig.1.5. Fitting an on/off switch in the battery connector

The current consumed by the micro:bit will depend on the supply voltage and the amount of use the board is making of the LED supply. Devices connected to the I/O pins (such as external LEDs and relay drivers) will further add to the load. Typical supply currents can range from as little as a few mA to several tens of mA depending on what the board is doing.

Useful information on micro:bit power consumption and battery capacity can be found respectively at: **www.reuk.co.uk/wordpress/microbit-power-consumption/** and **www.reuk.co.uk/wordpress/microbit-battery-capacity/**.

The battery holder supplied with the standard micro:bit kit is not fitted with a switch, so it becomes necessary to repeatedly connect and disconnect the power connector. If left connected, the batteries will drain unnecessarily and since this type of power connector is not designed for repeated connection and disconnection it is advisable to incorporate a switch in the supply connection (see Fig.1.5). Alternatively, battery connectors fitted with switches are available from some suppliers and these can usefully replace those supplied with the basic micro:bit kit.

Finally, one neat solution to the need for a battery pack is available from Kitronik (**www.kitronik.co.uk**) with their MI:power board (see Fig.1.6). The MI:power board fits snugly behind the micro:bit (see Fig.1.1) and has a 3V coin cell (CR2032), on/off switch, and a piezo buzzer. The MI:power board is connected directly to the 3V, GND and P0 connections on the micro:bit. The built in buzzer is connected to P0 (the default output pin when using the audio functions in the Block Editor software).

Maximum I/O current ratings

From the Nordic Semiconductor datasheet, the maximum current drive that can be obtained from an I/O pin is 5mA and no more than three outputs can be configured to provide this current (ie, a total of 15mA from the three output lines). In addition to limiting the output current for resistive loads you should also avoid connecting loads that are highly reactive (inductive or capacitive). Loudspeakers, solenoids and motors in particular may generate significant back-EMF whenever current is removed from them and the reverse voltages generated can exceed the maximum ratings for the GPIO pins. We will be looking at the micro:bit's I/O capability again in Part 2.

If you wish to use the micro:bit's 3.3V DC power (available from the edge connector) to supply external circuitry you need to keep in mind the total load on the on-board regulator. This device (a KL26Z) is rated at a maximum of 120mA when the board is deriving its power from the USB connector. Since the on-board devices consume a total of 30mA this leaves only 90mA for external circuitry (including whatever current is supplied by the GPIO pins). In practice, we recommend that you limit the external supply to no more than 50mA.

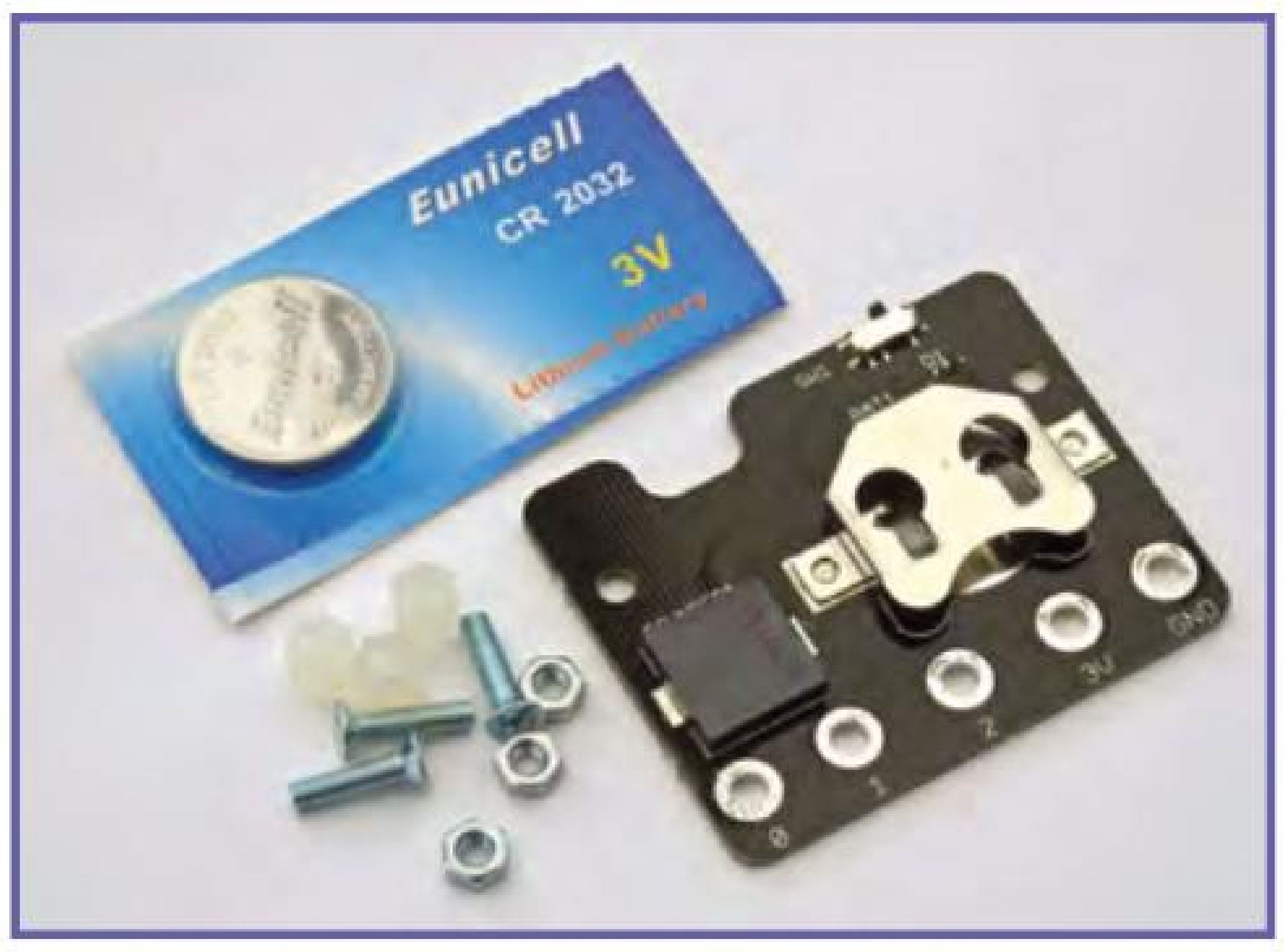


Fig.1.6. The MI:power board designed for attaching to the rear of a micro:bit

Programming environments

Thanks to its intended use as a platform for teaching coding, the BBC micro:bit supports several quite different programming environments. The most basic is a visual environment known as Code Blocks. Code Blocks dispenses completely with text-based coding and uses a simple drag and drop programming environment that is very easy to learn and makes an ideal starting point for anyone with no programming experience.

Using Code Blocks it is possible to assemble a working application in a matter of minutes and then have the graphical source (basically a picture of what the code will be doing) converted on-line into a hexadecimal file which can be downloaded to the host computer before copying into the micro:bit represented as a USB drive. This is all extremely easy but relies on a working Internet connection to the web-based application via the user's browser. In practice, this is extremely straightforward and it avoids several of the annoying complexities associated with other microcontroller development environments.

All of the development environments are freely accessible at the BBC micro:bit website: **www.microbit.org**. Note that both code editing and compilation are performed on-line, so you will need to have a web browser and an Internet connection in order to get going. When you open the website in your browser you just need to click on 'Create code' to get started, after which you will be able to select the programming environment that you wish to use. Currently the choices are:

- Microsoft Block Editor
- Code Kingdom Javascript
- Microsoft PXT (currently only available in a beta version)
- Microsoft Touch Develop
- Python

Microsoft Block Editor

Microsoft Block Editor is a very simple visual editor with a user-friendly drag-and-drop interface. The editor is designed to introduce structured programming. If you want to avoid the complexities of a text-based interface this is the one to start with. Later, you can convert scripts produced by Microsoft Block Editor into scripts that will work with Microsoft Touch Develop, once again providing a straightforward upgrade path to text-based coding.

Code Kingdom Javascript

Like the Microsoft Block Editor, the Code Kingdom's Javascript editor also provides you with a drag and drop environment in which each block represents a chunk of code. The interface makes it possible to switch easily between the visual environment and a text-based editor. Code Kingdom's Javascript makes the transition to text-based programming relatively straightforward.

Microsoft PXT

Microsoft's Programming Experience Toolkit (PXT) provides a coding environment that supports both a block-based editor and JavaScript. It also provides support for low-power wireless peer-to-peer communication.

Microsoft Touch Develop

Another package from Microsoft, Touch Develop is intended for use with mobile touchscreen devices (such as tablets and smartphones). The software can also be used with a conventional PC, keyboard and mouse. Touch Develop can be used to produce platform-independent web-based applications. Unfortunately, Touch Develop is not currently compatible with the standard Android browser. If you need to develop your code on an Android platform you will need to change your browser to Google Chrome.

MicroPython

Readers will already be familiar with Python from an earlier *Teach-In* that introduced the Raspberry Pi. MicroPython uses a text-based editor (there is no graphical programming environment) but this will probably not be a great concern for those with previous coding experience. There is currently plenty of support for MicroPython from an active community of developers and enthusiasts.

Which one to use?

If you have no previous experience of coding, we recommend that you start with the Microsoft Block Editor. This uses a highly intuitive visual environment and it will give you a taste of coding without having to resort to editing text. At some later stage, you will probably find the need to move to text-based editing and at that point we would suggest the MicroPython environment as this language is both well supported and available for multiple platforms. In next month's *Teach-In 2017* we will be taking a closer look at MicroPython for the BBC micro:bit together with a simple development environment that will allow you to program and flash your code off-line.

Microsoft Block Editor

The Microsoft Block editor environment is shown in Fig.1.7. On the left of the screen you will find a library of available code blocks sorted into the following categories:

- Basic
- Input
- Loops
- Logic
- Variables
- Maths
- LED
- Music
- Games
- Images
- Pins
- Devices

The centre of the display provides a coding area for you to assemble blocks of code. Blocks can be selected from the library on the left before dragging and dropping them into your code. Once there, blocks can be dragged around and linked together in order to produce a complete program. It's as simple as that!

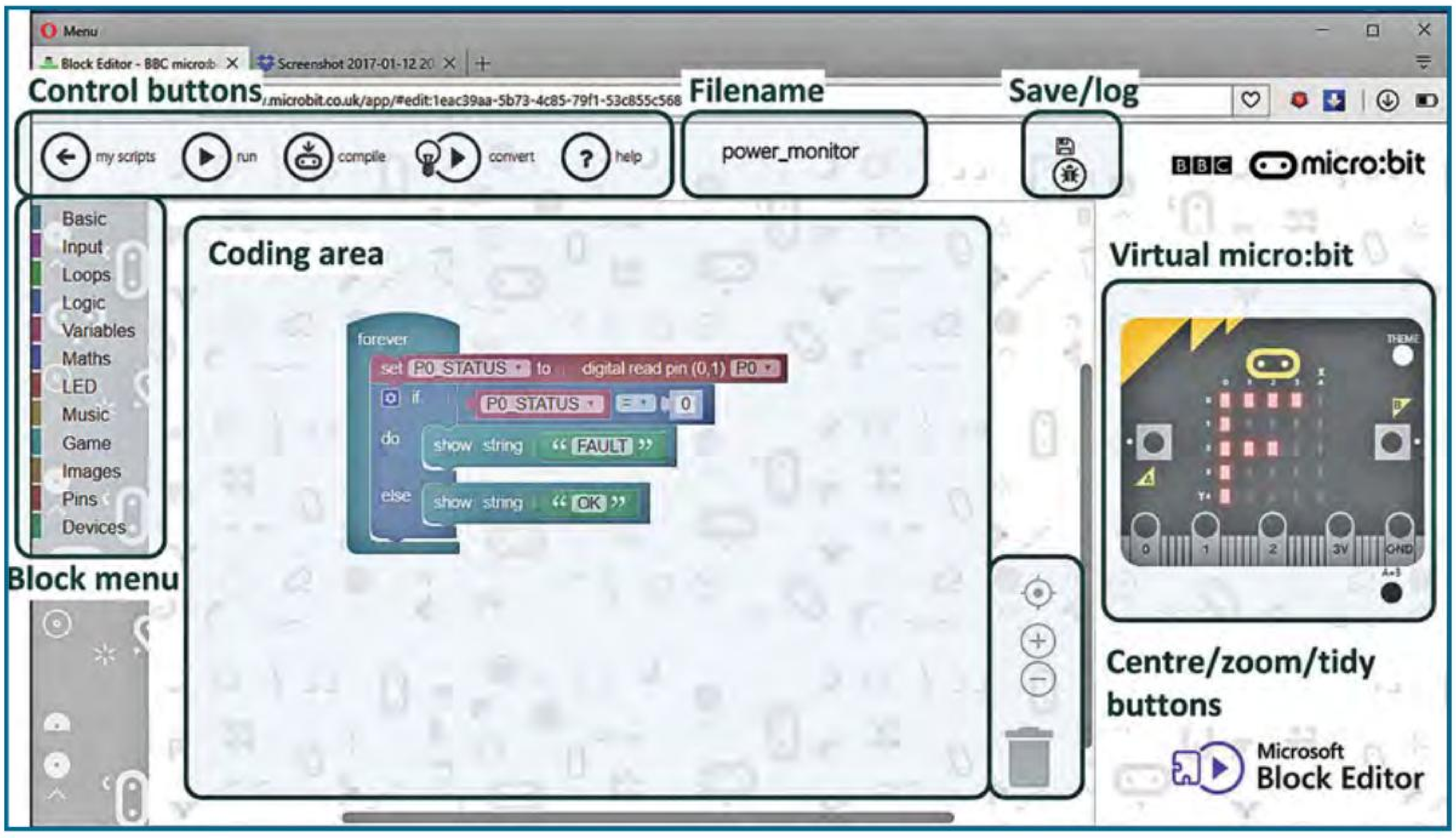
The button controls at the top provide you with the options to run, compile and convert your work to a text-based file. The log button provides a log of your activity (useful for debugging). Right-clicking on the tidy button will allow you to collapse, expand or clean-up your blocks.

On the right of the Microsoft Code Editor screen is a virtual micro:bit, complete with buttons and LED matrix display. The board can also be tilted and rotated. This useful feature allows you to test your newly developed program without having to connect and download your code to a real micro:bit. To test your code on a real micro:bit you will first need to connect it to your host computer via the USB cable and micro USB connector. If you have not done this before you may find that your host computer needs to locate a USB driver for your micro:bit.

The process of locating and installing the driver will usually be automatic, but you might see a notification that the driver has been located and is being installed. Finally, when you are ready to send your code to the micro:bit you just need to click on the buttons at the top of the screen to generate and download a hexadecimal (**.hex**) file. When successfully downloaded, this file will appear in your downloads folder. When you've located the downloaded hex file all you need to do is to send or copy it to the USB drive that your operating system has allocated to your micro:bit. On computers running Windows, the board will appear as a drive under Devices and drives; on a Mac it will appear as a new drive under Devices.

The MicroPython development environment is a build of Python specifically for the BBC micro:bit. Unlike Microsoft Block Editor, micro:bit Python does not provide you with a virtual micro:bit to play with, so if this feature is important to you, you might want to stick with the Microsoft Block Editor or move on to the Code Kingdom Javascript Editor. If you already have some Python experience or if you might be planning to move on to another, more advanced microcontroller, you might prefer to use the Python environment for your code development.

The Python environment uses a straightforward text editor and is supported by comprehensive documentation and tutorials. If you intend to develop more powerful applications that communicate with external devices (via UART, I^{2}C and SPI bus connections) you will find the Python libraries invaluable.



```
forever
  set P0_STATUS to  digital read pin (0,1) P0
  if  P0_STATUS = 0
  do  show string "FAULT"
  else  show string "OK"
```

Fig.1.7. The Microsoft Code Editor environment

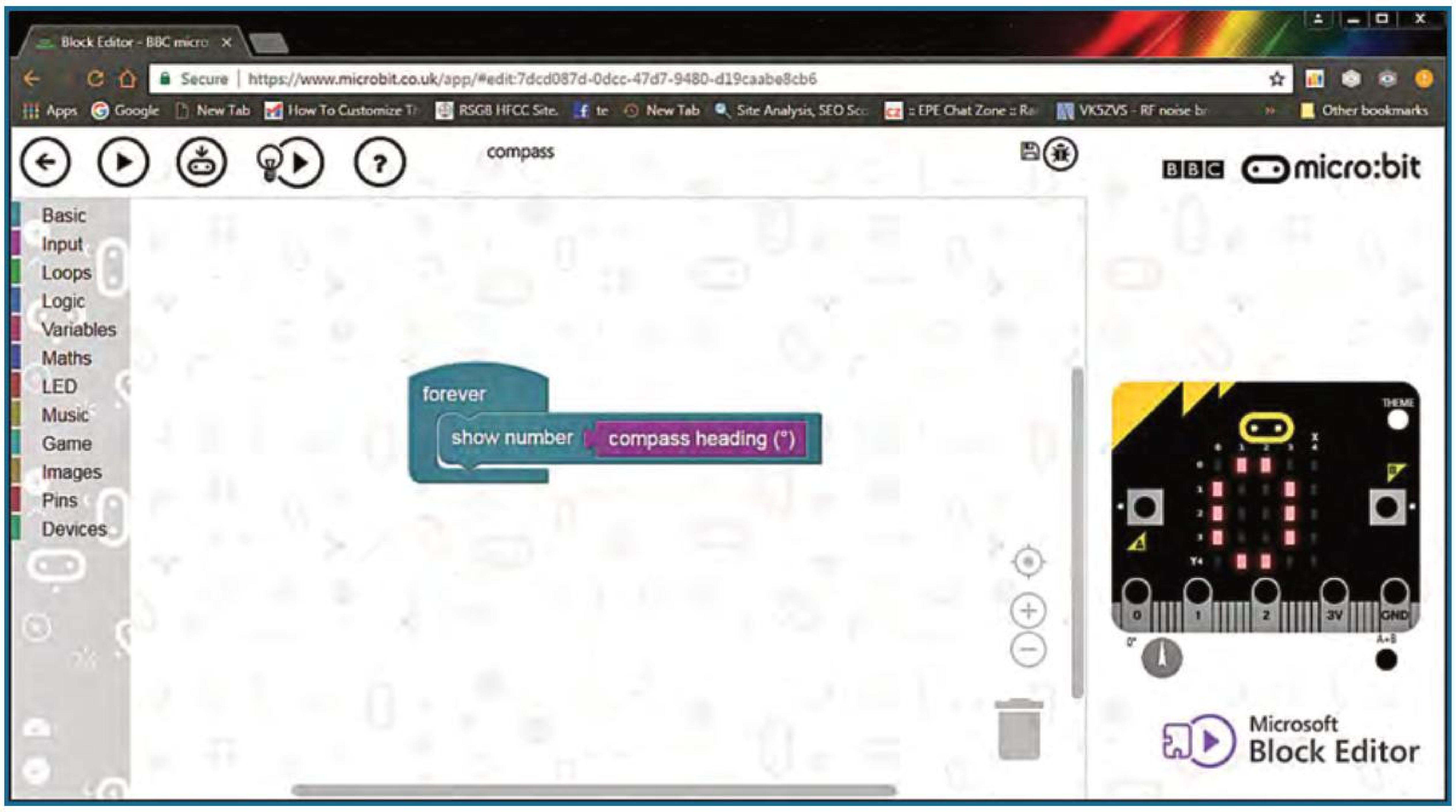


Fig.1.8. The Microsoft Code Editor being used to develop the electronic compass

Project: A simple micro:bit compass

Our practical projects have been designed to give you some hands on experience of using the BBC micro:bit and our first project builds into a very compact handy digital compass. The compass uses the micro:bit's on-board magnetometer device and displays the unit's current heading in degrees by scrolling it on the LED matrix display.

Programming using code blocks couldn't be much simpler. Just open Microsoft Code Editor in the usual way (see earlier) and type in a name for your program in the text field at the top of the screen (we chose a rather obvious name!). Your source file will be stored under this name and it will also be used in the name for the hexadecimal file resulting from the eventual compilation of your source code.

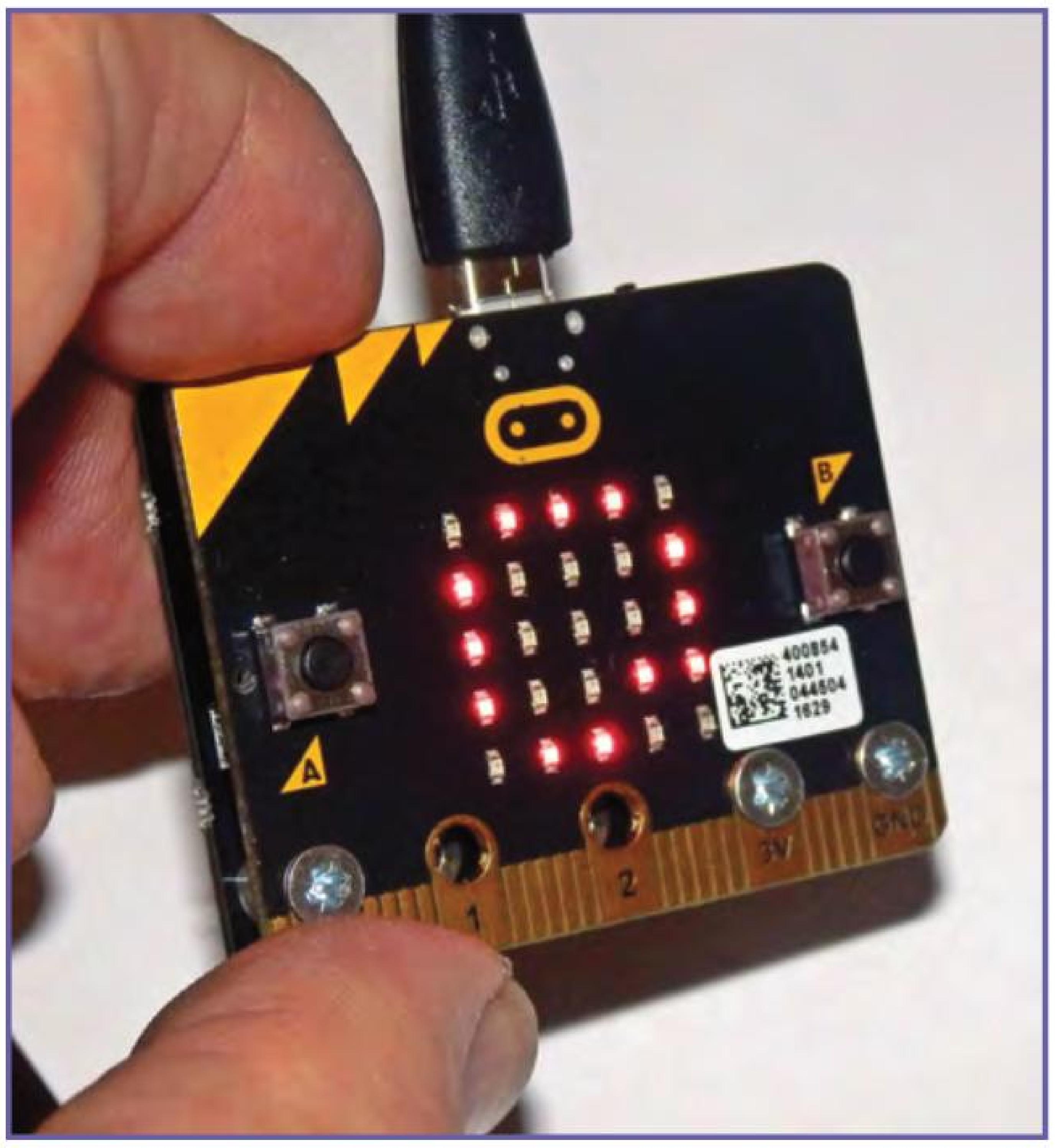


Fig.1.9. The calibration circle display

Get started by selecting **Basic** from the blocks menu on the left and then select the **forever** block and drag it into the code window. Position it roughly in the middle of the window. Next, return to the block menu and select **Basic** from the blocks menu for a second time. This time locate **show number**, select it then drag it into the code window and drop it into the vacant slot inside the **forever** block. You should find that it quickly and easily drops into place with the forever block readjusting itself to accommodate the new block of code. Now select Input from the blocks menu. Locate **compass heading** before dragging and dropping this new block into the grey box inside the **show number** block. Once again, things should move easily and the show number box should adjust itself to accommodate the new block.

What does this all do? The **forever** block ensures that the program continues in an infinite loop for as long as power is applied to the micro:bit. **show number** scrolls a number on the LED matrix display. The number displayed will be the current value of a variable called **compass heading** returned by the micro:bit's magnetic sensor and scaled into a value in degrees.

To test the code you just need to click on the run arrow (second from the left). When you do this the display will become illuminated and the current heading of the virtual micro:bit will be displayed (this should start at 0°). To rotate the virtual board, you can use the compass pointer (see Fig.1.8). As you rotate the micro:bit the heading will change.

Having tested our code we are ready to send it to our real micro:bit. Ensure that your micro:bit is connected to the USB port of your host computer (see earlier). Click on the compile icon (third from the left) and wait for a message to appear informing you that your hexadecimal file has been compiled and has been downloaded to your host computer. Navigate to your downloads folder, locate the file and send or copy it to the USB drive corresponding to your micro:bit.

As the hex file is being sent to the micro:bit you should notice the power LED flashing. When this stops the file transfer will be complete and the code will be running on the micro:bit. At this point you will be prompted (via a scrolling message) to calibrate the magnetic sensor. This is done by holding the board horizontally and moving it around in a circle to illuminate all of the LEDs around the periphery of the matrix display, in order to draw a complete circle (see Fig.1.9). When in the right position, the moving LED will remain illuminated so that you can move on to the next in order to display a complete circle. Once this has been done the sensor has been calibrated and headings will start to appear on the display. Note that to obtain an accurate bearing you will need to hold the board horizontally and keep it still for several seconds. The indications will be inaccurate whenever the device is used in proximity to permanent magnets and ferromagnetic materials generally. Finally, it is important to perform the initial calibration with the intended power source connected (particularly if the power source is the MI:power board). This board is in very close proximity to the sensor and can result in a constant error if calibration is performed before the power board is attached to the micro:bit.

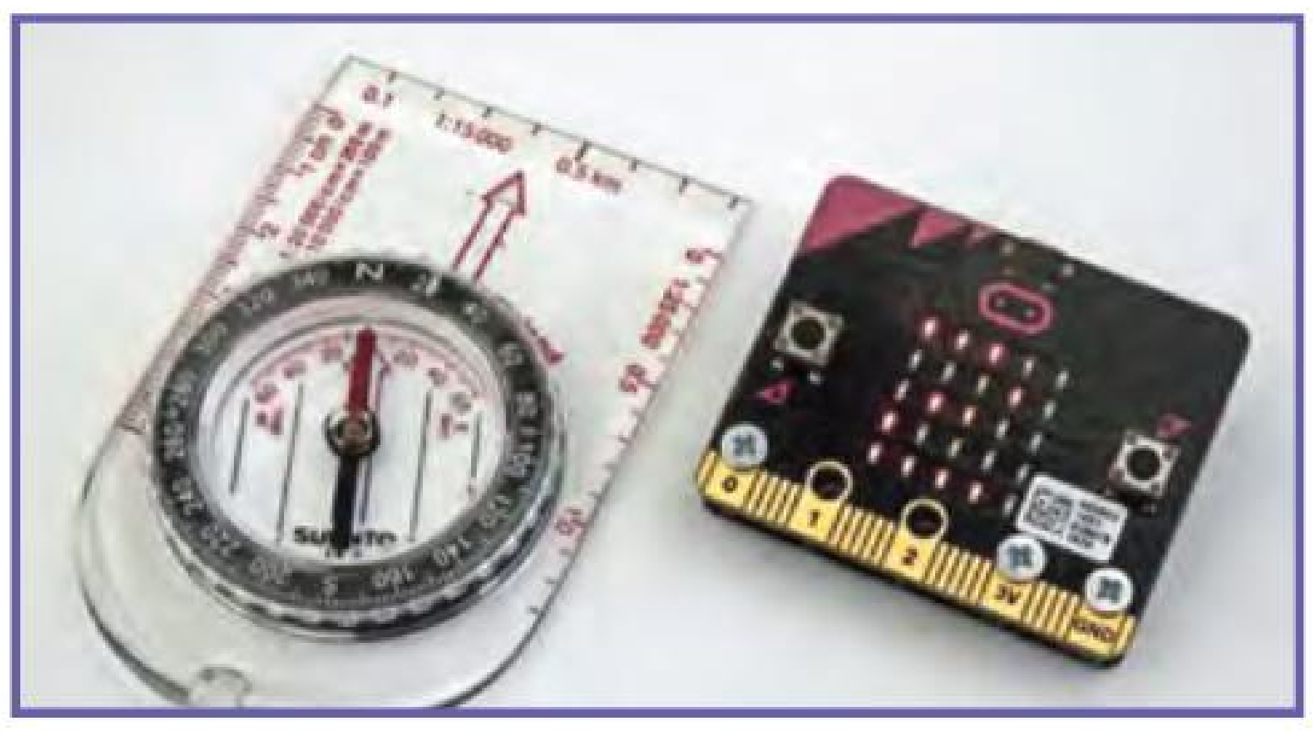


Fig.1.10. Checking the micro:bit compass against a conventional compass

Next month

In next month's *Teach-In 2017* we will delve into MicroPython and introduce the Mu editor that will provide you with an efficient method of programming your micro:bit without the need for an Internet connection. We will be also be investigating techniques for digital I/O using the micro:bit and our practical project makes use of the on-board accelerometer to produce a simple electronic spirit level.

GET THE LATEST COPY OF OUR TEACH-IN SERIES AVAILABLE NOW!

ON SALE in WHSmith and other independent newsagents NOW!

FREE CD-ROM

£8.99

ELECTRONICS TEACH-IN 8

FREE CD-ROM SOFTWARE FOR THE TEACH-IN 8 SERIES

FROM THE PUBLISHERS OF EPE EVERYDAY PRACTICAL ELECTRONICS

INTRODUCING THE ARDUINO
- Hardware – learn about components and circuits
- Programming – powerful integrated development system
- Microcontrollers – understand control operations
- Communications – connect to PCs and other Arduinos

EPE EVERYDAY PRACTICAL ELECTRONICS TEACH-IN 8

SOFTWARE FOR THE TEACH-IN 8 SERIES

PLUS...
PIC n'MIX
PICs and the PICkit 3 - A beginners guide. The why and how to build PIC-based projects

ISBN 978-1-896805-30-4

Teach-In 8 – Exploring the Arduino

This exciting series has been designed for electronics enthusiasts who want to get to grips with the inexpensive, immensely popular Arduino microcontroller, as well as coding enthusiasts who want to explore hardware and interfacing. Teach-In 8 provides a one-stop source of ideas and practical information.

The Arduino offers a remarkably effective platform for developing a huge variety of projects; from operating a set of Christmas tree lights to remotely controlling a robotic vehicle through wireless or the Internet. Teach-In 8 is based around a series of practical projects with plenty of information to customise each project. The projects can be combined together in many different ways in order to build more complex systems that can be used to solve a wide variety of home automation and environmental monitoring problems. To this end the series includes topics such as RF technology, wireless networking and remote Web access.

PLUS: PICs and the PICkit 3 - A beginners guide

The why and how to build PIC-based projects. An extra 12 part series based around the popular PIC microcontroller.

FREE COVER-MOUNTED CD-ROM

Containing the software for the two series

PRICE £8.99

(includes P&P if ordered direct from us)

PRE-ORDER YOUR COPY TODAY JUST CALL 01202 880299 OR VISIT www.epemag.com

NET WORK

by Alan Winstanley

Mission Impossible...

WELCOME to this month's *Net Work*, the column written with Internet users in mind.

The Internet has become so deeply ingrained into our ecosystem that most of us can be forgiven for taking the technology for granted. We have an entire generation that has never known life without the web, and as the laws of unintended consequences play out in real time, the explosion of online services is having an impact in some unforeseen ways. The author's local bank is shuttering its doors for the last time because everyone is supposedly 'banking online' and more consumers are choosing home deliveries of groceries ordered via the web, conveniently saving time and travel while forcing them to jostle for an empty 'delivery slot' and organise their lives around it as a consequence.

The web has made life easier than ever for those who are keen to repair, adapt or refurbish things, which I suspect includes most *EPE* readers. Some recent examples show just how indispensable the web has become to hobbyists and enthusiasts. After searching online a week or two earlier, the author has just received from California an 'impossible-to-find' Li-Ion battery for a Panasonic shaver, and an all-important assembly diagram was unearthed online too. A new shaver foil from Germany followed and (as I'm sure readers will want to know) some Williams Lectric pre-shave lotion arrived all the way from Chicago; the postman bearing the fruits of my productive web surfing. A legacy Brother laser printer is now sporting a new feed roller and pick-up pad, located online in Germany after a UK dealer let me down.

There's plenty more in this online Aladdin's emporium if you care to search, but it's worth reminding readers in Britain that if you pay using a credit card through PayPal, you lose the consumer protection that you would enjoy if you paid the supplier directly. You're buying from PayPal, not the supplier, and your statutory rights are replaced by PayPal's 180-day refund policy, with PayPal appointing itself as the arbiter of all disputes. For minor transactions this is probably not a worry, but buyers might think twice before making a serious purchase online using PayPal. In turn, traders face the risk of 'cowboy customers' who abuse the system with ruses such as mailing back an empty box and demanding a refund, hoping PayPal will play along. Sadly, the arm's-length remoteness of the Internet makes such fraud a seemingly victimless crime in the eyes of its perpetrators, and this has become part and parcel of today's online life.

Gadgets galore

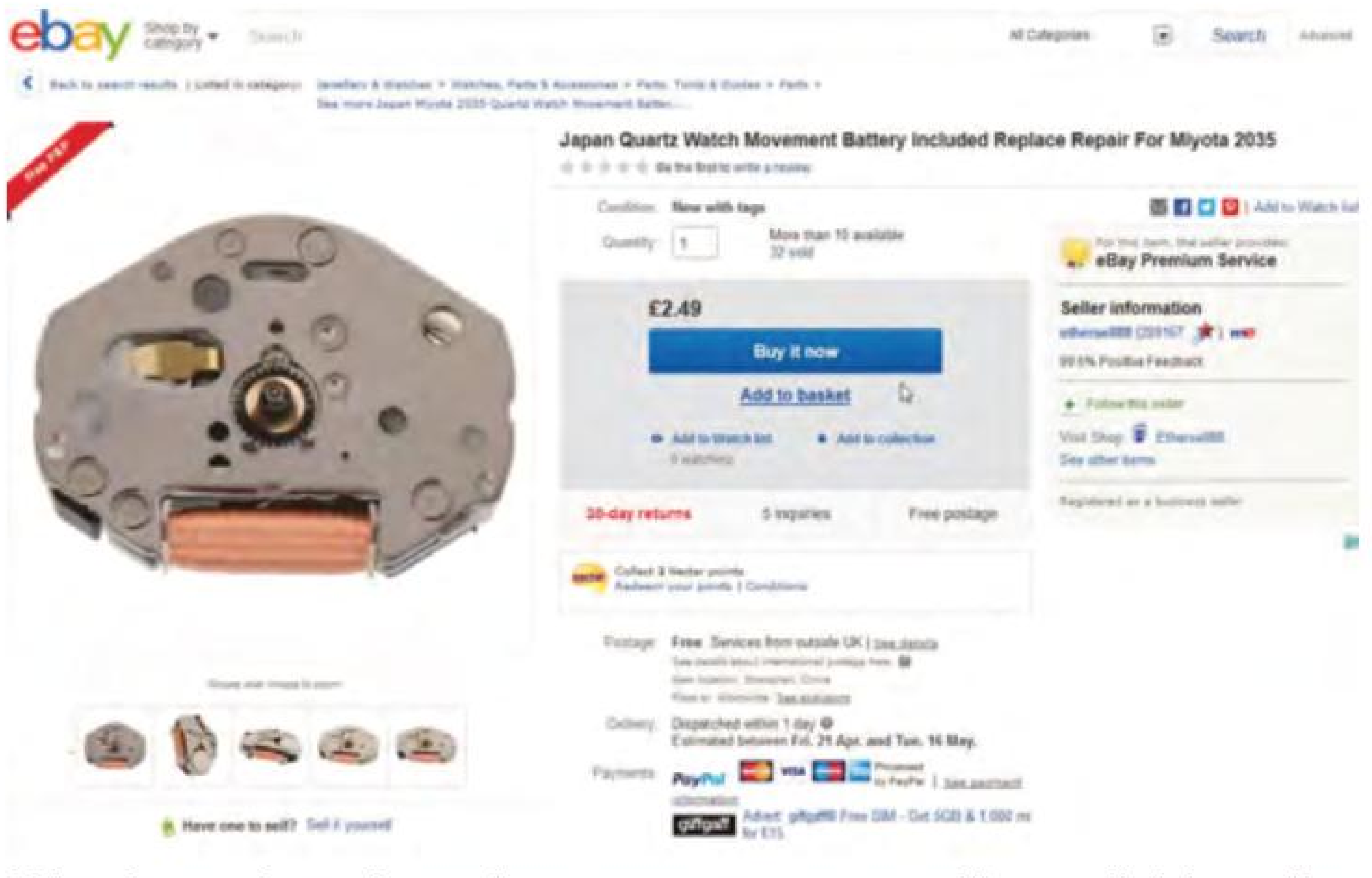
Gadget-selling Far Eastern websites such as AliExpress, Goodluckbuy and Banggood have got their acts together too, with mobile apps offering extra discount deals. A tiny new camera module for an HTC smartphone was recently delivered from China, and YouTube proved to be a rich source of how-to videos that enabled a nerve-wracking phone repair to be undertaken successfully. (A pack of different-size guitar plectrums (eBay) makes useful prying-open tools on plastic enclosures.)

The vivid green LEDs in an Eagle-brand LED nightlight (sourced on eBay) were swapped out for orange top-hat LEDs, once AliExpress delivered a set of Y-blade long-reach screwdrivers and an eBay seller supplied some orange LEDs for just a few pence each. The converted nightlight, which was not worth making from scratch, works wonderfully on my landing at night, enabling me to bask in its amber glow.

The web turned up trumps – or nearly anyway – when trying to repair my Pure Evoke Flow IP radio receiver, a birthday gift that I first reviewed nearly a decade ago. I tune into a US radio station which, as I write these words, is finally closing down its FM channel after many years and going online instead. (The friendly DJ in South Carolina graciously namechecked me before going off air for the final time.) In fact, I struggled to tune in at all as the Evoke's vivid yellow OLED display was fading fast, a victim of old age – I had to go underneath my desk to check it! Many other Evoke users have reported the same problem. Hunting online, a replacement looked a simple matter and other fans highlighted the display manufacturer, Taiwan's Bolymin, along with a part number that turned out to be only available from Britain's RS Components. It is presently halfway through its six-month lead time, so we will see who blinks first or gives up.

Thanks to information like this and more found on the web, there is a fighting chance of giving the radio a new lease of life, even if my favourite radio station is sadly no more. The DAB radio's British designers, Pure, was itself sold off by Imagination Technologies to Austria's AVenture GmbH last year.

Still with DIY repairs in mind, an enormous range of watch repair tools are sold on eBay and Amazon. These tools enable you – if your eyesight allows – to swap quartz watch batteries easily. A jeweller quoted £50 to swap a quartz movement on an inexpensive watch, so it was time to check out what's available online. Tools that push out strap pins, gadgets that unscrew or pry off a watch case back, and lever-presses that close them back together again – were all available on the web and could soon pay for themselves, much to the chagrin of my local jeweller. A quartz watch Miyota movement (£6.00) arrived from Greece, and specialist tools for removing and affixing watch hands came from China in a convoy of little packets. The web taught me that standard watch movements – called *calibres* – are found in many popular watch brands and their size



Japan Quartz Watch Movement Battery Included Replace Repair For Miyota 2035

Condition: New with tags

Quantity: 1 More than 10 available

£2.49

eBay Premium Service

Seller information

Watch repair tools and movements are readily available online is measured in French *lignes*. For mass-produced watches, the maker merely designs the case and strap, which can be made in Hong Kong, and drops in a standard movement costing a few pounds.

Armed with new insights like these, there's no denying the empowering effect that the Internet has had, with inside information, products, parts and tutorials now just a click away. Sadly, however, my DIY watch repair was a failure, as a mangled second-hand will testify! It was fun finding out though.

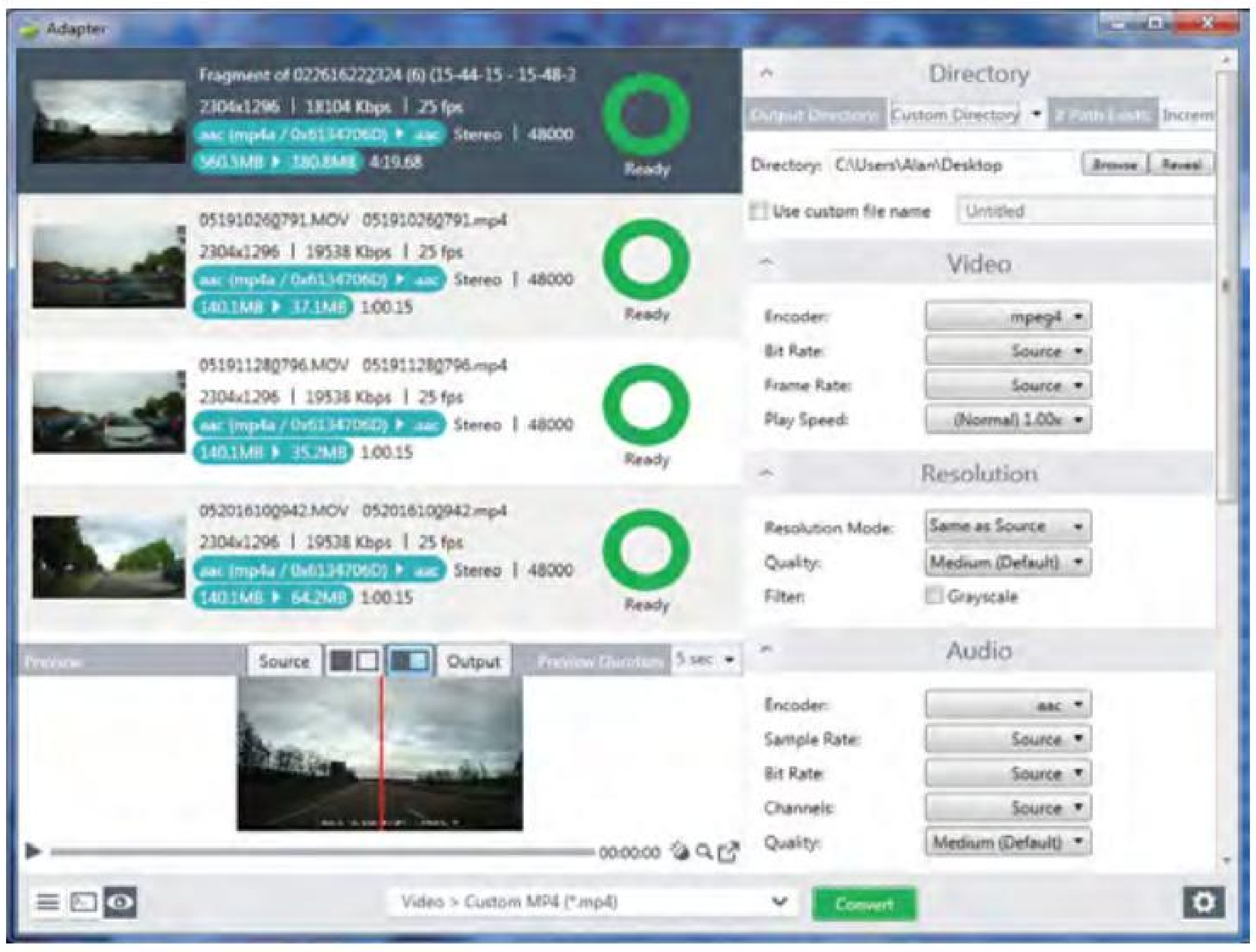
Dashcams and Facebook

Increasing numbers of traders, including Chinese vendors sell merchandise using 'FBA' (Fulfilled By Amazon) where the parcel-peddling monolith takes care of all logistics and customer order processing on the seller's behalf. This can create a worrying disconnect between the customer and the supplier, with buyers sometimes reliant on Amazon's review or Q&A system to get technical support – if they're lucky. FBA vendors tend to chop and change, making it hard to know who you are dealing with or whether they will disappear overnight. If you want to know how FBA works, details are here: **http://tinyurl.com/zjd9mrh**

In the July 2016 issue I mentioned a car dashcam branded as K&F (Kent Faith, a Chinese seller of photo accessories) that I sourced from an Amazon FBA seller. The generally excellent 1296P HD camera was bundled with some Windows software that constantly locked up when viewing journeys on Google Maps. As I mentioned in the article, the problem was caused by its out-dated reliance on Google Maps that no longer integrated with the software properly. The best solution was found in RegistratorViewer, an excellent program written by the late Vadim Kozlov that handled dashcam **.mov** files with ease. It is still available free from **www.registratorviewer.com/index_en.html**. Just run the **.exe**, point it to the camera's memory card and pick Bing Maps instead.

I noted some memory card issues with this camera just as the FBA seller morphed into the oddly-named 'Beschoi', so I wondered if I had been left stranded with a device that didn't record properly. For once, though, Amazon's customer feedback pages yielded a very helpful email address and I was quickly sent a flash upgrade by the mysterious Beschoi. The upgrade process could be charitably described as 'somewhat non-English', but it worked and the camera's boot screen changed to Beschoi too. Happily the device has worked flawlessly ever since.

RegistratorViewer lets you trim the footage to export as a separate movie file. However, the resulting gigabyte-size files often make it impossible to share them or upload onto Facebook (which will simply throw them out), so the quest has been for a simple video converter that would compress larger **.mov** files into MP4s suitable for Facebook or YouTube. Many dubious graphics programs are sold online, but I finally found one that seemed to fit the bill (it's free!). **Macroplant Adapter** takes in unwieldy **.mov** files and compresses them into MP4s and allows many minutes' worth of video to be uploaded onto Facebook without losing too much detail. Over on Facebook, videos can then be viewed in HD mode (click the player's cogwheel icon and choose HD) and the quality is perfectly acceptable, especially on a smaller tablet or smartphone. The clarity was so good that Facebook kicked out another dashcam video, stating that the car radio music was infringing copyright. Facebook named the tune, as well!


Adapter
Fragment of 022616222324 (6) (15-44-15 - 15-48-2
2304x1296 | 18104 Kbps | 25 fps
aac (mp4a / 0x6134706D) ▸ aac Stereo | 48000
560.3MB ▸ 180.8MB 4:19.68
Ready
051910260791.MOV 051910260791.mp4
2304x1296 | 19538 Kbps | 25 fps
aac (mp4a / 0x6134706D) ▸ aac Stereo | 48000
140.1MB ▸ 37.1MB 1:00.15
Ready
051911280796.MOV 051911280796.mp4
2304x1296 | 19538 Kbps | 25 fps
aac (mp4a / 0x6134706D) ▸ aac Stereo | 48000
140.1MB ▸ 35.2MB 1:00.15
Ready
052016100942.MOV 052016100942.mp4
2304x1296 | 19538 Kbps | 25 fps
aac (mp4a / 0x6134706D) ▸ aac Stereo | 48000
140.1MB ▸ 64.2MB 1:00.15
Ready
Preview
Source
Output
Preview Duration 5 sec
00:00:00
Directory
Output Directory
Custom Directory
If Path Exists
Increm
Browse
Reveal
Video
Resolution
Audio
Convert

Directory: C:\Users\Alan\Desktop

☐ Use custom file name Untitled

Video
Encoder: mpeg4
Bit Rate: Source
Frame Rate: Source
Play Speed: (Normal) 1.00x

Resolution
Resolution Mode: Same as Source
Quality: Medium (Default)
Filter: ☐ Grayscale

Audio
Encoder: aac
Sample Rate: Source
Bit Rate: Source
Channels: Source
Quality: Medium (Default)

Video > Custom MP4 (*.mp4)

Macroplant Adapter is a useful free program for Windows and Mac; it has a range of functions, including titling and captions

After experimenting with Adapter I found the software's 'Video Custom MP4' setting worked well. Other formats include **.avi** and animated gifs. You can also add layers to a video, eg, for text and audio, and **.srt** movie caption files can be imported too. This has yet to be actually tested, because unfortunately the program repeatedly crashed on the subtitle dialogs, but this bug may well be fixed in the future. Details on creating **.srt** subtitle caption files for your movies can be found at: **http://tinyurl.com/lezax5b**. Both Mac and Windows versions of Adapter are available. So if you want to convert some quick videos for Facebook, try it free at: **www.macroplant.com**

Smarter spearphishing

EPE readers know all too well how vigilant you must be when surfing the Internet, handling files or dealing with suspicious emails. Some criminal attempts at 'phishing' are almost embarrassing and can be dismissed instantly, but a hard core of determined criminals is becoming extremely sophisticated in its efforts to trick victims into visiting a website or opening a document that will attack their PC. Only once have I come close to falling victim to such tactics, when a close friend's email was hacked and the fraudsters impersonated her style of writing very well, but then the penny dropped that something wasn't quite right. I lost no money, but I admit it was a close thing. When confronted by such social engineering, human intuition can be more powerful than you think, so ask yourself, 'does it pass the sniff test?' If something doesn't quite 'smell' right somehow, tread *very* carefully indeed.

This week, I received a spearphishing email that shows just how clever these crooks are becoming. Spearphishing is a highly targeted attack aimed at an individual, perhaps using personal data stolen from a website, club, association or other source to add to its supposed authenticity. For reader reference, the email is reproduced below and it contained my name in the subject and supposedly my home address in the body. It's likely that the sender's name and email address had been spoofed. Probably, the crooks knew nothing else about me, but it was a very cunning attempt to pique my interest, hoping I would open a Word file and run a malicious macro.

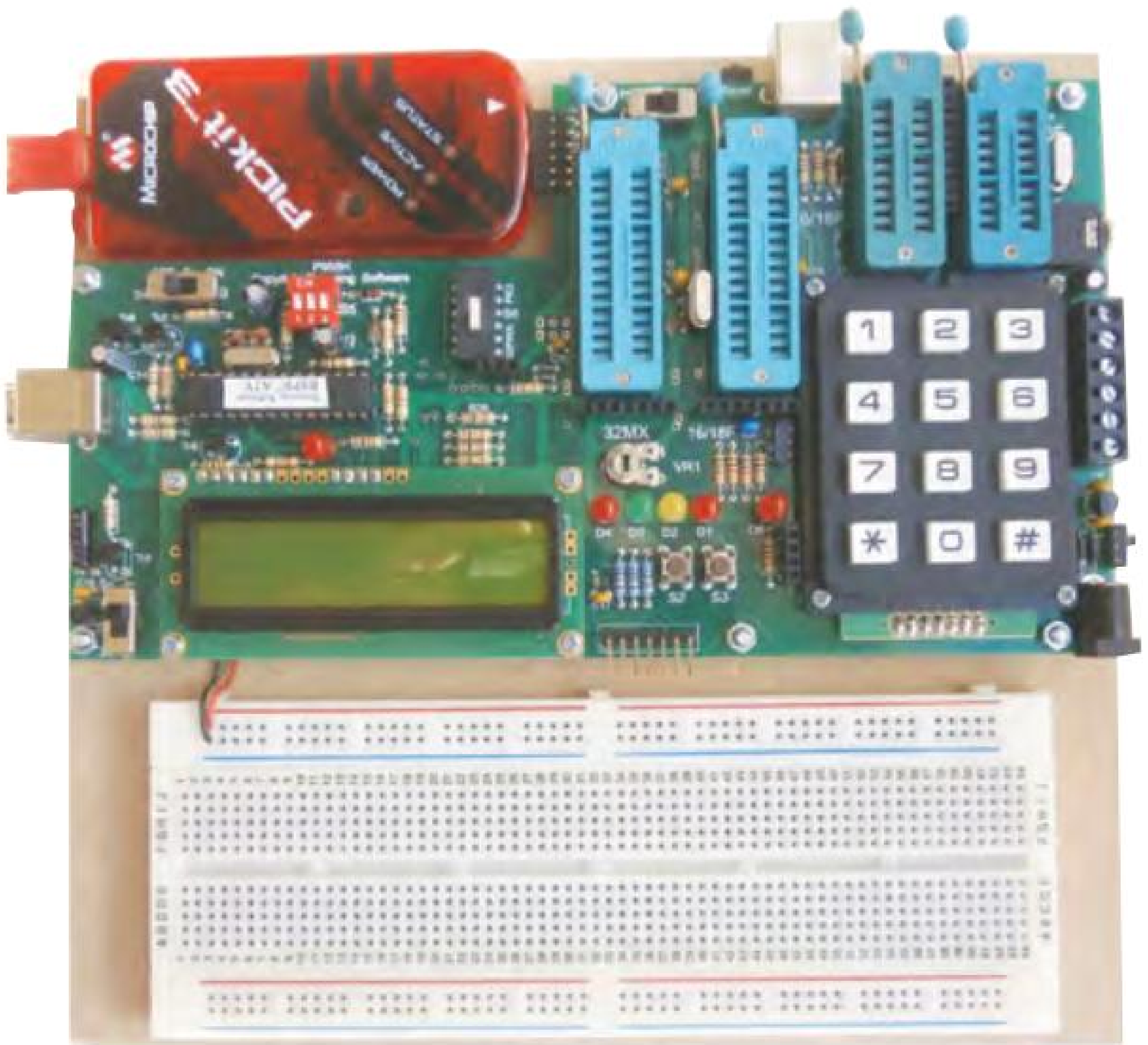
```
To: Alan Winstanley
Date: Tue, 28 Mar 2017 16:54:10 +0000
From: XXXXXXXXXXXXXXX
Subject: Alan

Good day to you, Alan!
I am bothering you for a very significant matter. Allhough you don't know me, but I
have considerable ammount of data concerning you. The fact is that, most probably
mistakenly, the information of your account has been emailed to me.
For instance, your address is:
XXXXXXXXXX XXXXXXX
XXXXXXXXXXXX
XXXXXXXX
XXXXX
XXXX XXX
I am a law-abiding citizen, so I decided to alert may have been hacked. I pinned
the file - Winstanley.dot that was sent to me, that you could explore what data has
become available for deceivers. Document password is - 9583
Sincerely,
xxxxx xxxxxxx
```

Obviously, the mail was deleted and the file attachment was triple-shredded. A macro could install a keylogger that relays banking keystrokes back to criminals or installs malware, ransomware or a spamming tool. By default, in my Word program macros are disabled, and readers should do the same. Go to: Options / Trust Center / Disable all macros from running.

See you next month for more *Net Work*. You can email the author at: **alan@epemag.net**

32 bit PIC Training

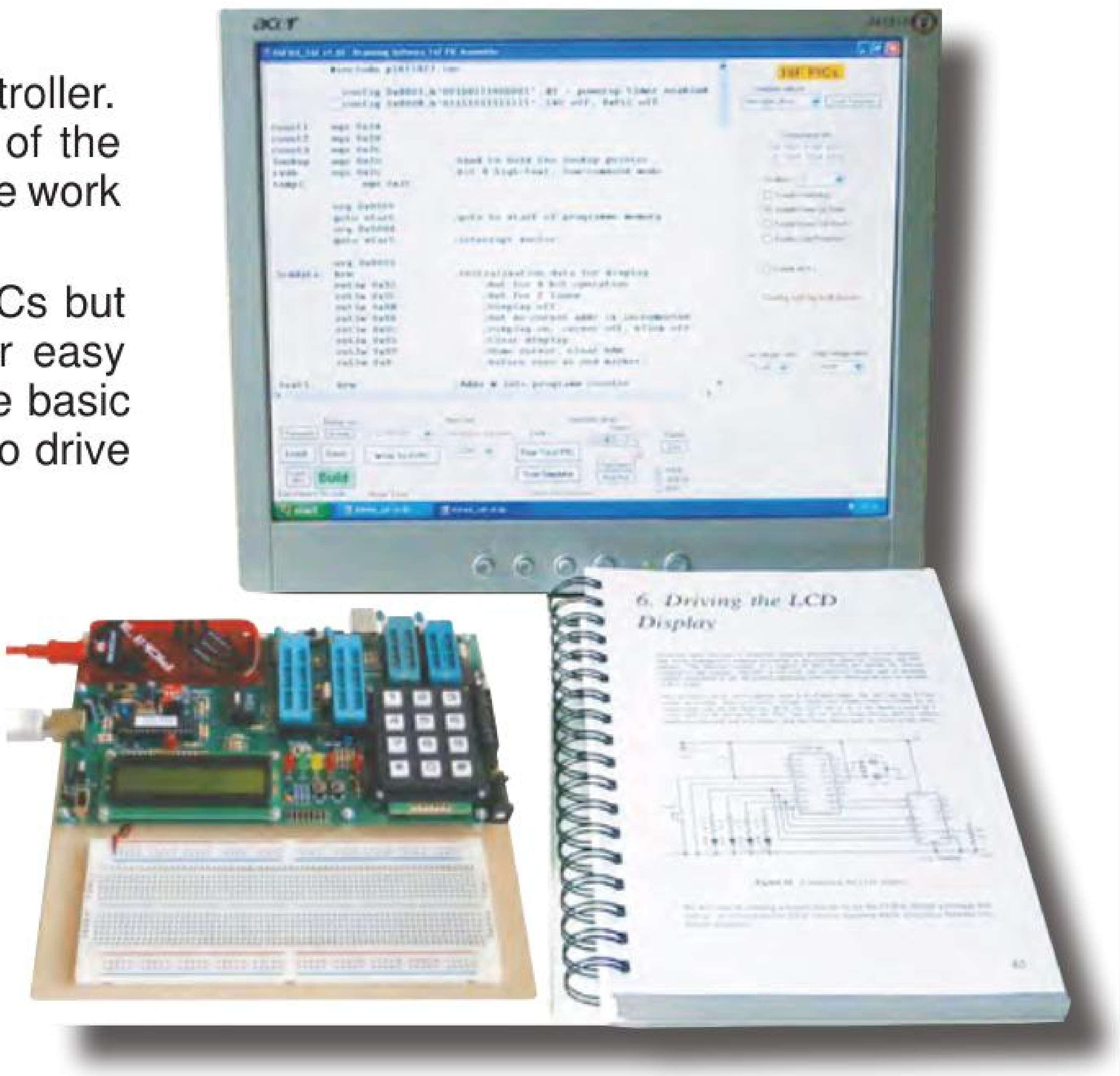
by Peter Brunning



32 bit PICs are massive in all respects. Huge amounts of programme memory, huge amounts of temporary storage memory (RAM), huge amounts of input/outputs, and very fast processing speeds. And fortunately for us experimenters Microchip have included a dual in line version.

The problem is that 32 bit PICs are far to complex for absolute beginners. So the P955 training circuit has been designed to work with both 32 bit and 8 bit PICs. The idea is to start learning about PICs using assembler with 8 bit PICs. Then learn C with 8 bit PICs, study serial communications using 8 bit PICs, and finally study C programming using 32 bit PICs. It is a simple approach to a subject that has no limit to its ultimate complexity.

The Brunning Software P955H PIC Training Course



We start by learning to use a relatively simple 8 bit PIC microcontroller. We make our connections directly to the input and output pins of the chip and we have full control of the internal facilities of the chip. We work at the grass roots level.

The first book starts by assuming you know nothing about PICs but instead of wading into the theory we jump straight in with four easy experiments. Then having gained some experience we study the basic principles of PIC programming, learn about the 8 bit timer, how to drive the alphanumeric liquid crystal display, create a real time clock, experiment with the watchdog timer, sleep mode, beeps and music. Then there are two projects to work through. In the space of 24 experiments two project and 56 exercises we work through from absolute beginner to experienced engineer level using the latest 8 bit PICs (16F and 18F).

The second book introduces the C programming language for 8 bit PICs in very simple terms. The third book Experimenting with Serial Communications teaches Visual C# programming for the PC so that we can create PC programmes to control PIC circuits.

In the fourth book we learn to programme 32 bit MX PICs using fundamental C instructions. Flash the LEDs, study the 16 bit and 32 bit timers, write text to the LCD, and enter numbers using the keypad. This is all quite straightforward as most of the code is the same as already used with the 8 bit PICs. Then life gets more complex as we delve into serial communications with the final task being to create an audio oscilloscope with advanced triggering and adjustable scan rate.

The complete P955H training course is £254 including P955H training circuit, 4 books (240 × 170mm 1200 pages total), 6 PIC microcontrollers, PIC assembler and programme text on CD, 2 USB to PC leads, pack of components, and carriage to a UK address. (To programme 32 bit PICs you will need to plug on a PICkit3 which you need to buy from Microchip, Farnell or RS for £43).

Prices start from £170 for the P955H training circuit with books 1 and 2 (240 × 170mm 624 pages total), 2 PIC microcontrollers, PIC assembler and programme text on CD, USB to PC lead, and carriage to UK address. (PICkit3 not needed for this option). You can buy books 3 and 4, USB PIC, 32 bit PIC and components kit as required later. See website for details.

Web site:- www.brunningsoftware.co.uk

Mail order address:

Brunning Software

138 The Street, Little Clacton, Clacton-on-sea,
Essex, CO16 9LS. Tel 01255 862308

PIC n' Mix

Mike O'Keeffe

Our periodic column for PIC programming enlightenment

PICs and the PICkit 3: A beginner's guide – Part 11

THIS MONTH, we are going to tackle Lesson 11, which (mostly) looks at 'indirect addressing'. As mentioned every month, I recommend having a read of the previous articles in the series. It's not necessary for this article, but you will gain a greater insight into PICs and what we're trying to achieve here. You will also need the following software and hardware:

1. Purchase the PICkit 3 Low Pin Count Demo Board (**http://tinyurl.com/h2jj2ek**)
2. Purchase the PICkit 3 Programmer + USB Cable (**http://tinyurl.com/zcpx3le)**
3. Download *PICkit 3 Starter Kit User's Guide* (**http://tinyurl.com/jyqfeuk**)
4. Download MPLAB X IDE (**http://tinyurl.com/hmehqja**)
5. Download XC8 Compiler (**http://tinyurl.com/h5g9k5l**)
6. Download Example code for PICKit3 Starter Kit (**http://tinyurl.com/z2dm5k3**)

A word of warning, this subject is not straightforward and there are some difficult concepts to grasp; so I'm going to break it down into manageable pieces with the aid of diagrams. Starting off with the part of the PIC system that is 'addressed' – namely, the memory. Then, a brief description of what addressing is and finally we'll move on to pointers.

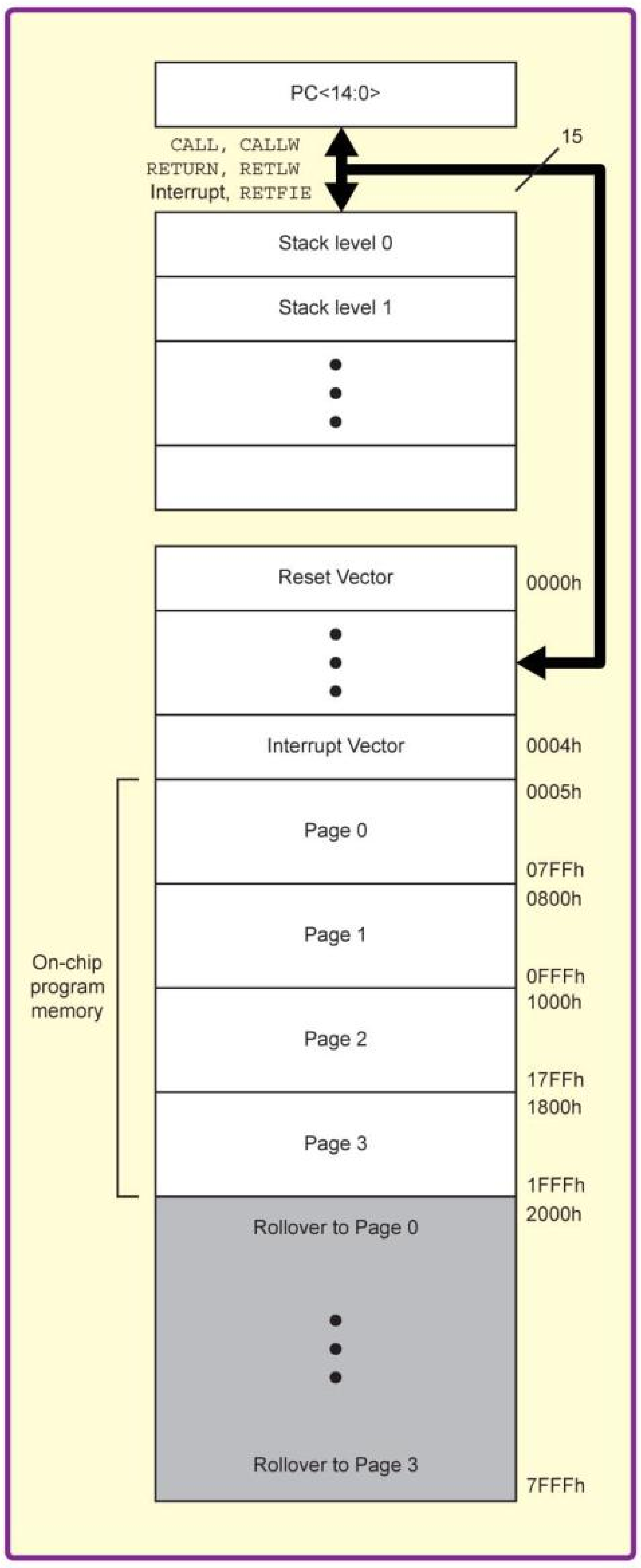


Fig.1. Program memory map and stack for PIC16F/LF1825/1829

Memory

Before we look at indirect addressing, we need to know what it is we are addressing. When we write our code in MPLAB X and compile it, we need to program new code onto the PIC microcontroller. The PIC16F1829 has three types of memory:

- Program memory
- Data memory
- Data EEPROM memory

The program memory is the location where new code is sent. A program counter then executes, in order, each command in the code that is stored in the program memory. When a reset occurs, the program counter goes back to the start of the program memory and each command is executed again.

Fig.1 shows the program memory map and stack for the PIC16F1829. You can see the program counter (PC) followed by the stack, which stores information about the active subroutines of the program. This is followed by the reset vector at 0000h (which is the same as 0x0000, both hexadecimal) and the interrupt vector at 0004h (0x0004). Below that we have the on-chip program memory, which is where our code is stored. There's a lot more going on in this diagram, but that's a discussion for another day.

The data memory is implemented with RAM (random access memory). It contains special registers and general-purpose registers. This is where runtime variables are stored. RAM is volatile, so when the microcontroller is reset or the power is removed, all of the data in this type of memory is deleted – ie, the contents are forgotten.

By contrast, the non-volatile data memory area is made of EEPROM. Variables written to this area won't get deleted during a power off or a reset. (We'll cover this in Lesson 15 in a few month's time.)

Addressing

Lesson 11 in the *PICkit 3 Starter Kit User's Guide* aims to explain the various addressing modes, but to be honest, I found the explanations heavy going and difficult to read. The focus on the lesson is on indirect addressing, which the *User Guide* covers in detail, as well as the other addressing modes: inherent, lateral and direct.

Broadly speaking, *direct* addressing means an instruction refers directly to the address being accessed. That is, the instruction itself contains the address of the location. *Indirect* addressing uses an address held in a register or other location to determine what memory location to read or write. The idea here is that the instruction itself isn't directly telling you the address to access, but rather indirectly telling the CPU where to find that address – hence 'indirect'. At this stage it's best to focus on what is actually happening instead of dry theoretical definitions of how each mode works, so let's go straight to an example.

Take a variable instantiation:

```
int some_var = 4;
```

This initialises a variable called `some_var` and stores the value 4 in it. In this case, it is best to imagine the 4 is stored inside a box called `some_var`. Fig.2 shows a diagram of this box. When we look inside this box, we can see it has the number 4. Now imagine this box is in a warehouse with many other boxes, called by different variable names and storing different values. In order to find the box called `some_var`, we would need a unique address. This address

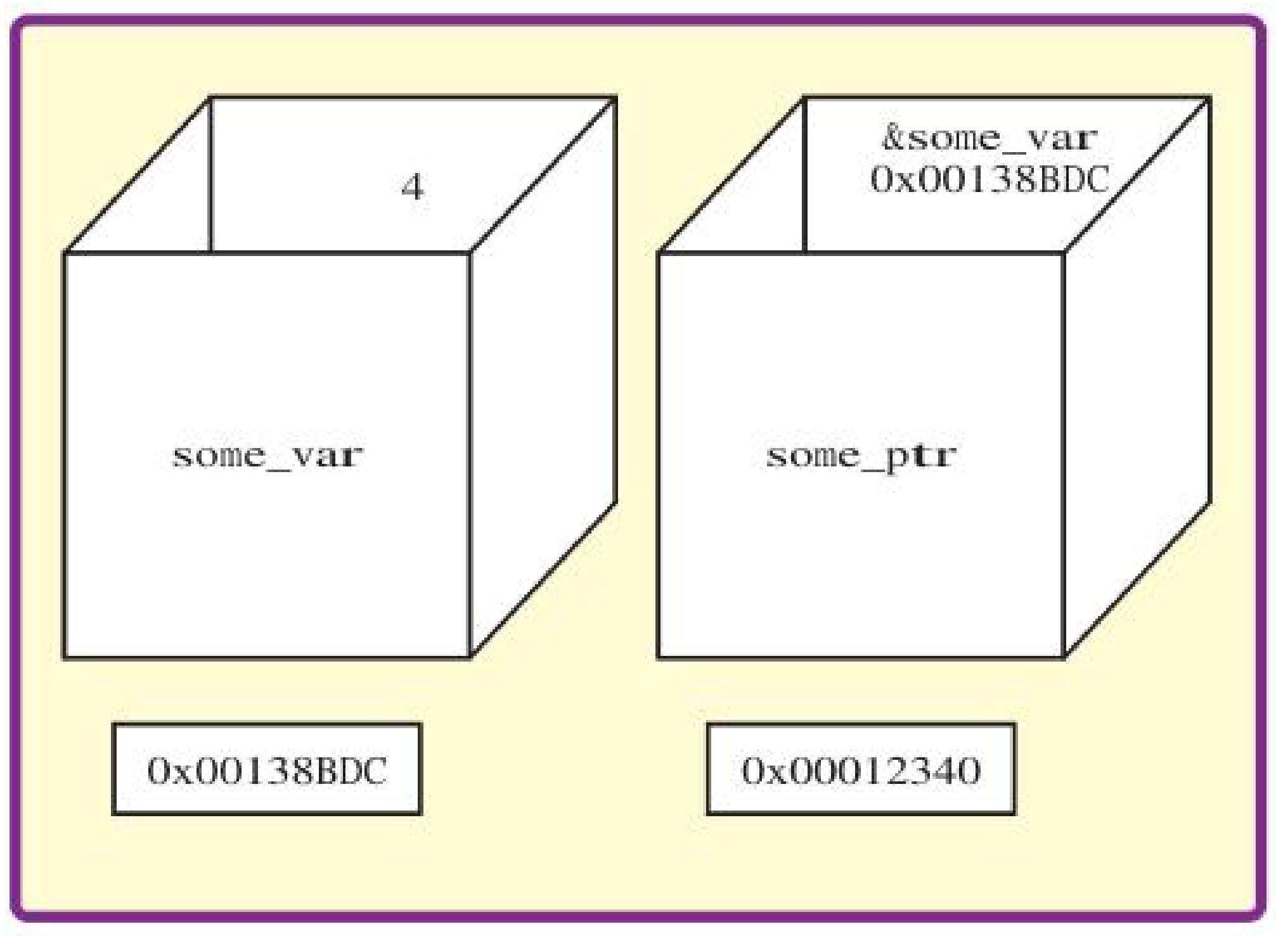


Fig.2. Box/variable and box/pointer with memory locations.

is the exact location of the box in the warehouse. Every time we use `some_var`, our PIC will find the address of this box and then find the value inside this box.

In this analogy, the warehouse is our internal memory, the box is the variable and the number 4 is the contents. Now all we need is the memory location of that variable in memory. The variable `some_var`, like all other variables or constants, will have its own unique memory location in memory storing the value assigned to it. This memory location is automatically assigned when we instantiate the variable `some_var`.

Pointers

So far in our code, we've used variables, definitions and functions without caring how these truly work inside our PIC. We have our variable somewhere in memory, but how do we find out its address or memory location? We use pointers.

```
int *some_ptr;
```

A pointer is like a variable. When it is declared it will store a value, but instead of storing its own value, it will store the address of another variable. The code above initialises a pointer called `some_ptr`, note the asterisk (*) before the name, which tells us it is a pointer and not a variable.

```
some_ptr = &some_var;
```

In the line above we take the address of `some_var` and store it in the pointer. Note the ampersand (&) before `some_var`, which denotes the address of that variable.

In Fig.2, we return to the box and the warehouse analogy. On the left, we have the box called `some_var`, which stores the value 4. We have another box `some_ptr`, which stores the address of `some_var`. Below each box is the address of the memory location of each. Note the address of `some_var` can be seen in the box `some_ptr`.

This gets a little complicated when you want to point a pointer at another pointer. Pointers become extremely useful when you want to access a large number of memory locations with ease, like an array.

Arrays

Sometimes, we don't want to access just one variable, but a whole group of variables. Arrays can store a whole collection of variables of the same type. Instead of declaring a bunch of variables: `int var1`, `int var2`, `int var3`, `int var4` up to `int var8`, we could write `int var_num[8]` instead. This declares an array of eight variables with type `int`. In order to access any of these, we simply change the number in the brackets, ie `var_num[3] = 13;`

Pointers are often used with arrays as a convenient way to access each element in the array, quickly and efficiently. We can see this in the following code.

The code

In this example code for indirect addressing, a 'moving average filter' is created. Its operation is similar to taking the average of a set of numbers. However, instead of operating on just one set of numbers, there is a constant stream of numbers, in this case from the PIC's ADC input. In order to accurately calculate the average, we use a moving average filter. (Also known as a 'rolling' or 'running average' filter; used to smooth out fluctuations caused by external noise.) If it were implemented in hardware, it would simply be called a 'low-pass filter'.

The actual code is taken from *Lesson 4: Analog to Digital Conversion*. The only difference from that code is that here we apply the moving average filter for a smoother analogue input. For all intents and purposes, you probably won't notice any difference in the behaviour of the board unless it is near a lot of electrical noise.

```
#define NUM_READINGS 8
unsigned char average(unsigned char *ptr);
unsigned char adc(void);
unsigned int _sum = 0;
```

In the four lines above, we start by defining a constant called `NUM_READINGS`, which will be used later.

Before using a function, it needs to be declared before the main code. Here we declare a function called `average`, which takes an unsigned pointer to a char and returns an `unsigned char`. A second function called `adc` takes no value and returns an `unsigned char`. These are also known as the 'function prototypes' because they let the compiler know about the behaviour of functions used in the code before they are used. Further on, we will see the actual functions and their contents.

Last but not least, we initialise a variable called `_sum` and store a 0 in it.

```
void main(void) {
    unsigned char *ptr_queue;
    unsigned char queue[8] = {0};
    unsigned char i;
```

The main code starts by initialising a pointer called `*ptr_queue`. The next line is a new one, where we initialise an array or char and set each value to 0. This array stores eight values, all of which are now equal to 0. Last, a general-purpose `char i` is declared.

```
OSCCON = 0b00111000;
TRISC = 0;
```

We've seen these next two lines many times before. We set the clock to 500kHz using the `OSCCON` register, and set Port C to outputs using the `TRIS` register.

```
TRISAbits.TRISA4 = 1;
ANSELAbits.ANSA4 = 1;
ADCON0 = 0b00001101;
ADCON1 = 0b00010000;
```

Again, there's nothing new in the next four lines. Port RA4 is connected to the output of the potentiometer on the Low Pin Count board, so it is set as an analog input. Port RA4 is then set up as the source of the ADC, and the ADC module is enabled using the `ADCON0` register. `ADCON1` then sets the returned values to be left justified, the speed is set to FOSC/8 and the Vref is VDD. (This has all been covered in previous lessons.)

```
while (1) {
    ptr_queue = &queue;
    for (i = NUM_READINGS; i != 0; i--){
        LATC = (average(ptr_queue) >> 4 );
        ptr_queue++;
    }
}
}
```

This next piece of code is where all the action is. In the `while` loop, we take the address of the variable array `queue` and store it in the pointer `ptr_queue`. This pointer now points to the start of the array and not the whole array.

In the `for` loop, we start with variable `i` equal to `NUM_READINGS`, which is 8, as declared earlier. Each iteration decrements i until it is equal to 0, then exits. Effectively, this means NUM_READINGS dictates the 'number of readings' made in each averaging cycle. We could increase or decrease this number for smoother or less smooth outputs. Note the naming of this variable, which accurately describes what it is doing.

The next line takes the value stored in the variable, which ptr_queue is pointing to. In the first iteration, this is the first element in the array queue, which is queue[0]. This value starts off as 0, as declared earlier in the code. This value is then sent to the function average, which takes the first value (0) and sums it to the new value taken from the ADC. This value is then returned from the function, right shifted by four and stored in the Port C, which is where the LEDs are connected.

```
unsigned char average(unsigned char *ptr) {
     _sum -= *ptr;
     *ptr = adc();
     _sum += *ptr;
     return (_sum/NUM_READINGS);
}
```

As mentioned above, the previously declared function average is defined here. Taking it line by line it expects an unsigned char pointer to be passed to it when the function is called. Then we take the value stored in the variable that ptr points to, which is the first element in the array queue[0] (for the first iteration of the for loop mentioned above). This value is subtracted from the contents of _sum, which are initially 0. _sum is our moving average sum variable.

Next, we sample the ADC using the adc function and store the returned value in the variable that the ptr is pointing to, which is still queue[0].

Now we have a value in queue[0], we take that value (using the ptr to point to it again) and add it to the _sum variable.

Last, we want to return the averaged sum value divided by the number of samples taken.

```
unsigned char adc(void) {
     __delay_us(5);
     GO = 1;
     while (GO) continue;
     return ADRESH;
}
```

We've seen our final function adc many times in previous lessons. There's a small 5µs delay to allow the capacitor on the ADC pin to charge before starting the conversion by setting the GO command to 1. Then we wait for the conversion to complete and return the eight most-significant bits, which are stored in the ADRESH register.

Next month

I hope I haven't lost you completely this month! Indirect addressing is not the easiest topic, but it is important, so stick with it and *work* through the examples. Next month, we're going to look at a very useful function – look-up tables. Then we will finish this series with EEPROMs and a small project, which will attempt to use as much of what we've learned in this series. After that we shall bid *adieu* to the PICkit 3 Low Pin Count Demo Board and move onto new fun topics.

Not all of Mike's technology tinkering and discussion makes it to print.

You can follow the rest of it on Twitter at *@MikePOKeeffe*, up on *EPE Chat Zone* as *mikepokeeffe* and from his blog at *mikepokeeffe.blogspot.com*

pico Technology

THE PICOSCOPE® 4444

SEE THE DIFFERENCE

NEW

A NEW STANDARD IN DIFFERENTIAL MEASUREMENT
- 20 MHz bandwidth, 12 to 14-bit resolution
- 4 fully differential inputs
- 1000 V CAT III probes
- Low-voltage probes and current clamps

WHAT CAN YOU DO WITH THE PICOSCOPE 4444?

Switch mode power supplies are notoriously difficult to troubleshoot and characterize using grounded-input oscilloscopes, as much of the circuitry is floating or electrically isolated and often at mains voltage levels.

The PicoScope 4444 differential inputs give you the confidence to probe across circuits and components without concern about shorting floating voltages to ground.

For more information please visit www.picotech.com/PS515

Please contact Pico Technology for the latest prices before ordering.
Email: sales@picotech.com. Errors and omissions excepted.

CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Oscilloscope probes

A FEW MONTHS ago new *EPE Chat Zone* user ***simonbond*** posted a question about oscilloscope probes.

‘Just a simple query about the x1/x10 oscilloscope probe bandwidth trade-off. My new 100MHz Hantek scope says that the probe in the x1 setting limits the scope bandwidth to 6MHz, but to use the full bandwidth of the scope (I assume the full 100MHz), select the x10 setting. I thought the x1/ x10 would mean 60MHz. Not sure where the extra 40MHz comes in? Obviously I would like to have the full 100MHz, so should I buy some better quality probes? I use 50Ω coax and BNCs for all my connections to signal generators and counters. But I would be grateful for advice/explanation about the 6MHz/60MHz/100MHz question!’

Later in the discussion, frequent contributor ***741*** also asked in response to a comment from another frequent contributor ***zeitghost***, ‘Do probes still use resistive inner conductors?’

There is a lot more to a scope probe than ‘just a piece of wire’ connecting the circuit under test to the oscilloscope. Probe design takes into account the related issues of loading the circuit under test, bandwidth and the effect of the probe on the shape of fast pulse signals. To answer ***simonbond’s*** question we will look at the circuitry of x1 and x10 oscilloscope probes and discuss how this relates to the bandwidth. As it is part of the same story, we will also look at why scope leads use resistive conductors, as raised by ***741*** and ***zeitghost***. Our discussion here will be limited to what are called ‘passive probes’ – these are probes that only contain passive components – in other words, they do not provide active amplification.

Before getting into the details, it’s worth mentioning the meaning of ‘x1’ and ‘x10’ in the context of oscilloscope probes. This refers to the attenuation of the probe on the signal. So with a x1 probe the oscilloscope sees an input voltage equal to the voltage being measured (under ideal conditions), for a x10 probe the oscilloscope sees an input voltage which is one tenth of the voltage being measured. Oscilloscopes often have a x10 probe setting (manual switch or menu item, or automatic adjustment when the probes are plugged in) so that the voltage displayed represents the actual voltage measured, rather than the attenuated voltage from the probe.

It is common to find oscilloscope probes with switchable x1 and x10 settings, but higher quality x10 probes tend not to feature a x1 setting. Other attenuation factors are also available (eg, x100) but are less common. Attenuation may be useful if the voltage being measured is larger than the maximum input of the oscilloscope, but that is not the primary reason for using a x10 probe. As indicated by ***simonbond’s*** question, probes with higher attenuation factors are able to provide more measurement bandwidth and may be required to fully exploit the bandwidth of the oscilloscope.

Loading

There is a general rule that if you try to measure something then you will change the thing you are measuring. There is a large range of possible outcomes – the effect of the measurement on the measured parameter may range from infinitesimal to catastrophic. In the case of using electronic test equipment, such as multimeters and oscilloscopes, to measure or monitor the voltage in a circuit the effect on the measured by the measurement is called ‘loading’. In general terms, the instrument takes some input current that changes the currents in the circuit under test, resulting in a shift in the voltage being measured.

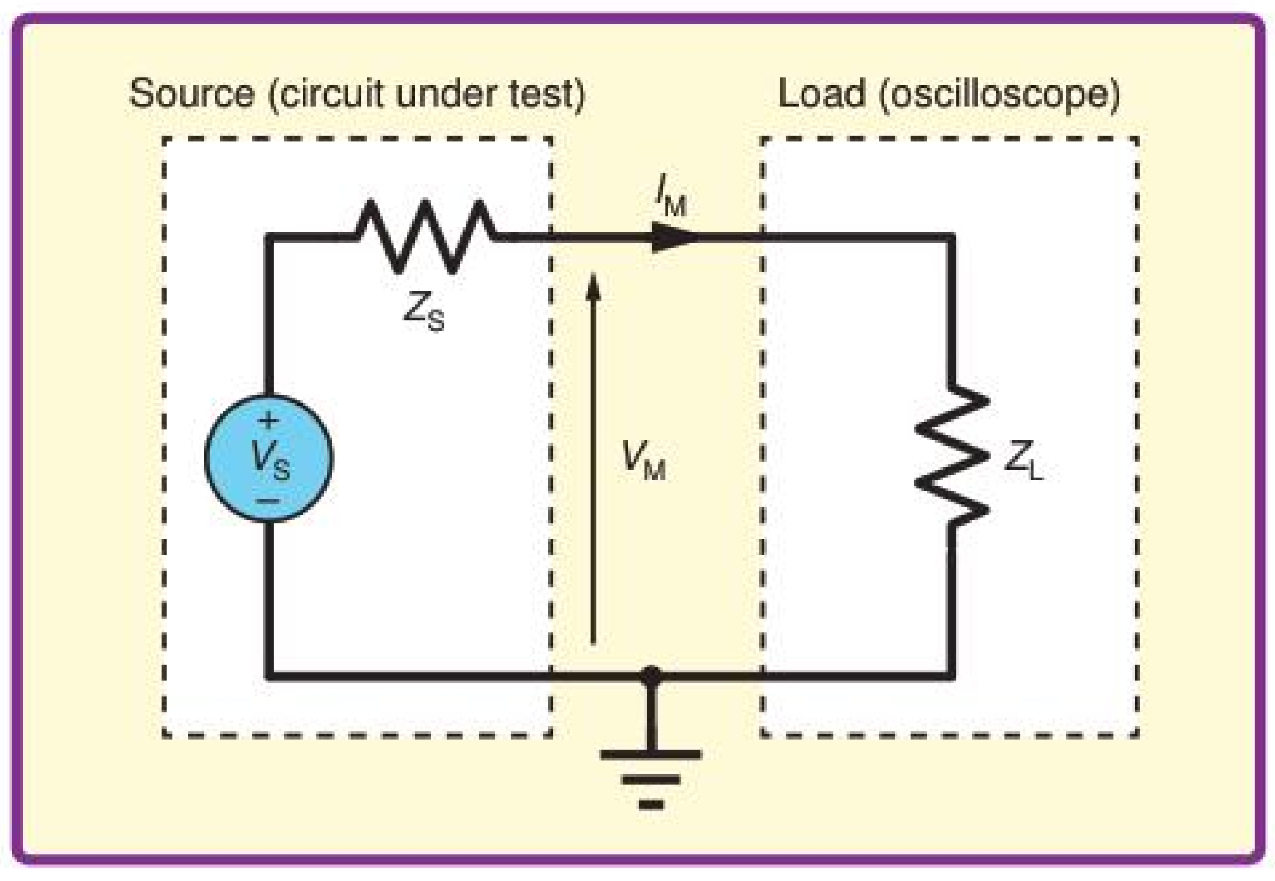


Fig.1. Equivalent circuit for a test instrument such as an oscilloscope connected to a circuit under test in order to measure a voltage

Fig.1 shows a generalised situation in a circuit where a source or output is connected to a load. This is an abstract representation of a vast range of possible cases where two electronic circuits or devices are connected together, including the situation where an oscilloscope is connected to a circuit under test. Here, the point in the circuit under test where the oscilloscope is connected is represented by a voltage source V_S and source impedance Z_S. The voltage we want to measure is V_S. The oscilloscope’s effect on the circuit is represented by the load impedance, Z_L. When the oscilloscope is connected it will cause a current I_M (measurement current) to flow through Z_S resulting in a voltage drop across Z_S. Thus the measured voltage, V_M, will not be the same as the voltage we are trying to measure, V_S. This is the loading effect.

The idea that any point in a circuit can be represented by a single voltage source and an impedance (resistor in the simplest cases) is based on Thévenin’s theorem. The theorem is named after Léon Charles Thévenin (1857-1926), a French telegraph engineer; although the theory was also developed 30 years earlier, in 1853, by Hermann von Helmholtz (1821-1894). Thévenin’s theorem states that a linear electronic circuit that comprises any combination of voltage sources, current sources and resistors, with two output terminals, is electrically equivalent to a single voltage source, V_S, and a single series resistor, R_S (Z_S in Fig.1).

Node impedance

In Fig.1 the two impedances form a potential divider. Thus, the voltage seen by the oscilloscope, or other instrument, is given by:.

$$V_M = \frac{Z_L}{(Z_S + Z_L)} V_s$$

We derive this equation using Ohm’s law to obtain the current through the two impedances (V_S divided by the total impedance) and applying Ohm’s law again to get the voltage drop across Z_L (multiplying the current by Z_L). From the equation, we confirm that if we want V_M to be as close as possible to V_S then Z_L must be much larger than Z_S. If Z_L is very much larger than Z_S then the measured voltage is effectively equal to the source voltage.

For a typical voltage measurement instrument we would expect Z_L to be large, maybe in the region of several megohms, and we would expect its value to be stated or implied in the instrument's specifications. This is straightforward at low frequencies (eg, for DC measurement using a digital voltmeter/multimeter), but a little more complex over wide frequency ranges, which we will discuss shortly.

The value of Z_S may be far less easy to determine – it is the Thévenin equivalent impedance, not an actual component value. In general, if the point of interest in the circuit is the output of a power supply, power amplifier, or similar circuit it is likely that Z_S will be relatively small and connecting the test instrument will probably not cause loading problems. Such points in circuits are referred to as 'low-impedance nodes'. On the other hand, if the point of interest in the circuit is only connected to low impedance nodes via large resistors, or other high impedances then it is likely to have a large Z_S and be susceptible to loading effects. It is then referred to as a 'high-impedance node'.

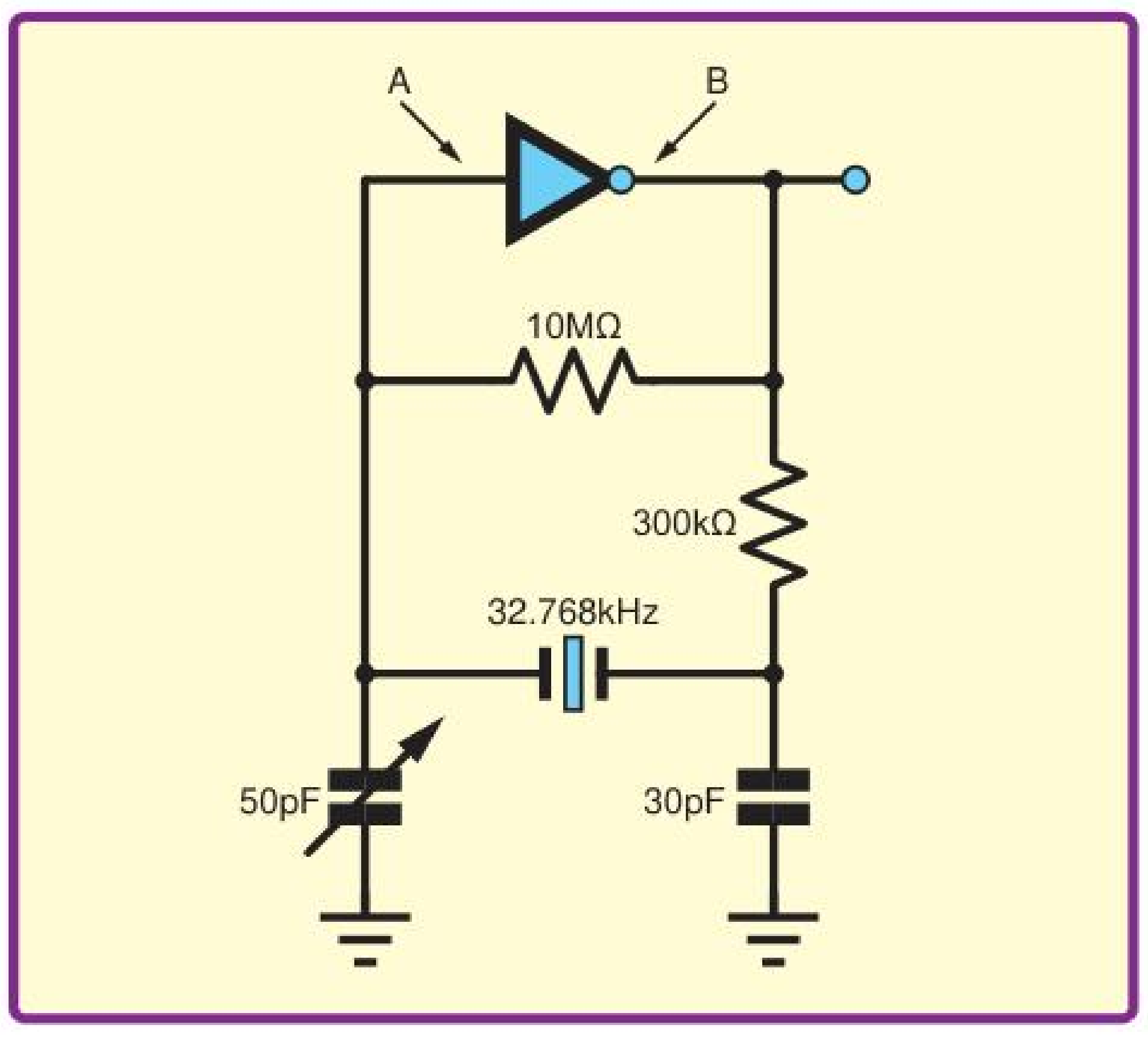


Fig.2. Circuit with low and high impedance nodes. Connecting an oscilloscope or other test instrument to point A may have a significant loading effect. There is less likely to be a problem measuring point B

The circuit in Fig.2 is a typical crystal oscillator based on a logic inverter. Point B in the circuit is a relatively low-impedance node as it is driven directly by the logic gate's output. Point A is a relatively high-impedance node because everything connected to that point has high impedance (at least at DC or low frequencies). Connecting a test instrument to point A in this circuit is more likely to disrupt its operation due to loading effects than connecting to point B. Even if disruption does not occur, the measurement at point A is likely to be less accurate unless the instrument input impedance is very high.

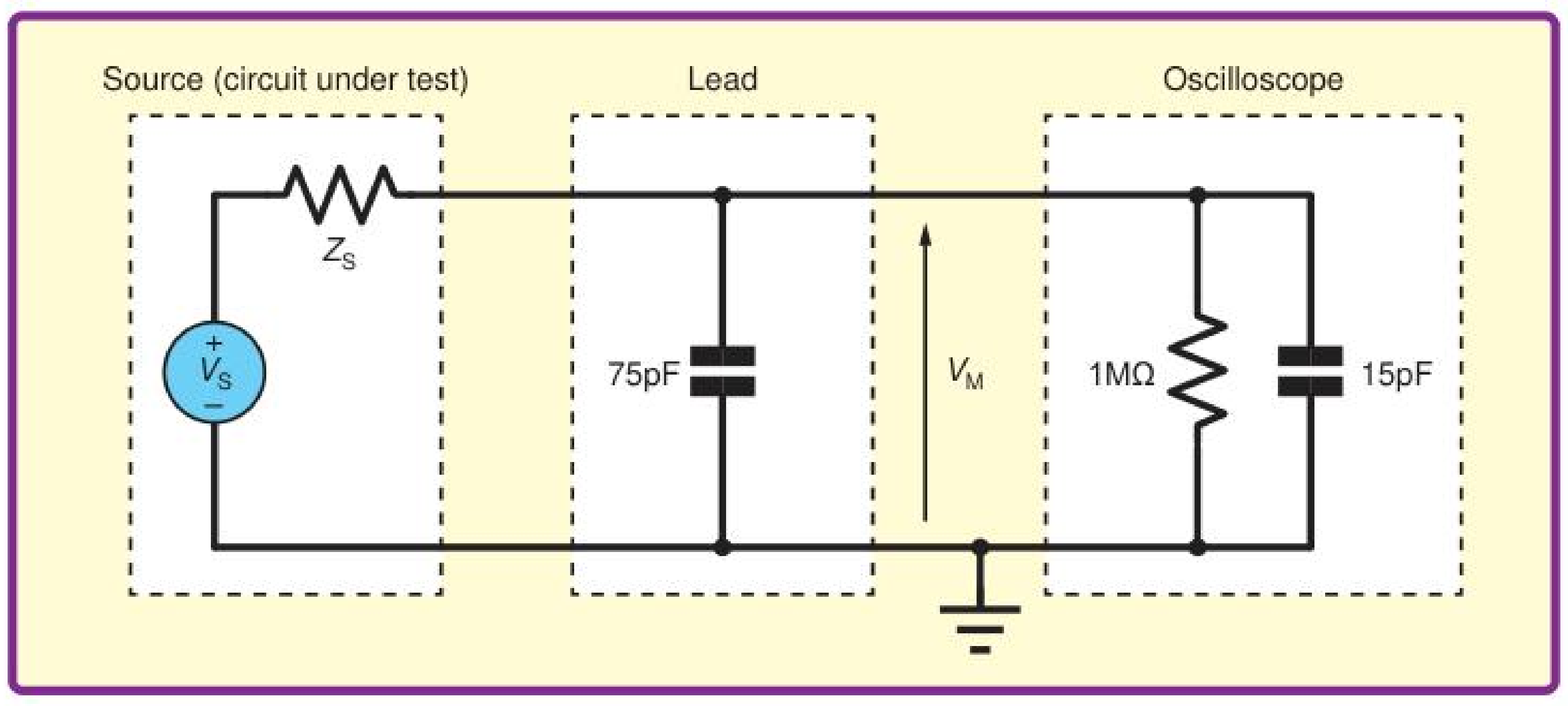


Fig.3. Equivalent circuit for an oscilloscope connected directly to a circuit under test (approximate circuit for a x1 passive probe)

Capacitive loading

So far, we have mentioned that loading may be frequency dependent, but have not looked at this in detail. At this point it is helpful to consider the specific input characteristics of a typical oscilloscope – is 1MΩ resistance in parallel with 10 to 20pF of capacitance. The probe lead also has significant capacitance, typically in the range 50 to 100pF. The circuit in Fig.3 represents the connection of an oscilloscope to a circuit under test. It is similar, but not quite the same as using a x1 probe. We will look at the differences between this circuits and a x1 probe later, but the circuit in Fig.3 is sufficient to consider basic loading effects.

At DC, the lead and scope input capacitances have infinite impedance and therefore the load impedance (Z_L) is simply 1MΩ. At higher frequencies we can calculate the effective resistance (reactance) of the capacitance (X_C) using:

$$X_C = \frac{1}{2\pi fC}$$

For example, at 6MHz with a total capacitance of 90pf, X_C is about 295Ω. This is in parallel with the 1MΩ resistance, but the effective resistance of the capacitance is so low that the 1MΩ is more or less irrelevant.

At high frequencies the effective input impedance of the scope is quite low. The user needs to ask how much this will load the circuit under test. If the oscilloscope is connected directly to a signal generator or low-impedance source the situation may be fine, but if the oscilloscope is connected to a high-impedance node in a circuit the loading effect on the signal of interest may be very significant.

x10 probe

The x10 probe adds a resistor and capacitor in parallel close to the probe tip (as shown in Fig.4) in order to increase the total impedance of the probe plus scope and reduce loading on the circuit under test. The signal is attenuated by a factor of ten, but the load impedance is increased by a factor of ten. In most cases this is a useful trade-off because, even after attenuation, the signal has sufficient amplitude to be displayed correctly and the loading is significantly reduced. For probes which have a x1/x10 selection switch on the probe, the switch (not shown in Fig.4) simply shorts out the resistor and capacitor in the probe, so the circuit is the same as that in Fig.3.

Fig.4 is an approximate circuit for a x10 probe. It is approximate because it ignores the small capacitance at the probe tip and represents the lead as a simple capacitance – both these approximations also apply to the circuit in Fig.3. (We will discuss the lead later.) For now, Fig.4 shows that at DC and low frequencies (where we can ignore all the capacitors) the x10 probe simply adds a 9MΩ resistance in series with the scope lead. This increases the total load resistance to 10MΩ – ten-times higher than the oscilloscope's 1MΩ input resistance. The 9MΩ and 1MΩ resistors form a potential divider, which attenuates the signal from the circuit under test by a factor of ten at the oscilloscope's input.

The presence of the capacitors in the circuit in Fig.4 means that the total load impedance will reduce as frequency increases. At high frequencies the capacitors will have much lower effective resistance than the resistors; for example, at 60MHz, we have 265Ω and 30Ω for the 10pF and 90pF capacitances respectively, a total of 295Ω, which is the same as the value calculated for the x1 probe at 6MHz (ten-times-lower frequency).

Fig.5 shows a plot of probe plus oscilloscope impedance against frequency for the x1 and x10 probe equivalent circuits in Fig.3 and Fig.4. The graph shows that the x10 probe (in combination with the oscilloscope input) has a load impedance that is ten-times higher than when using

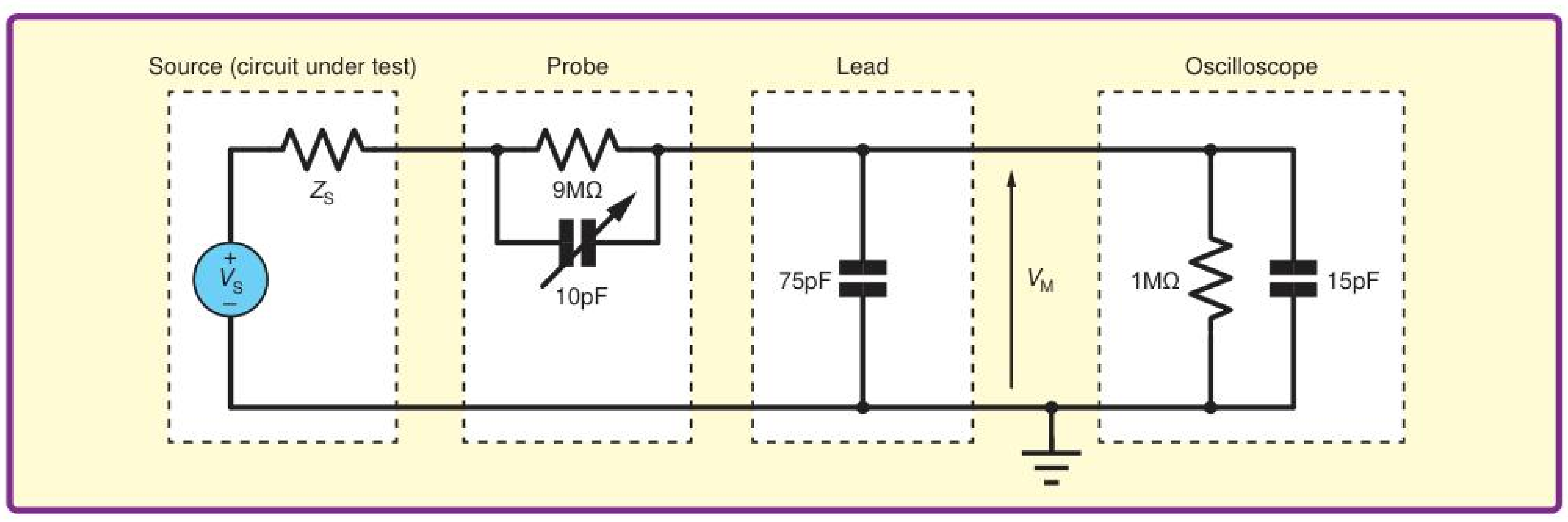


Fig.4. Equivalent circuit for an oscilloscope connected directly to a circuit under test (approximate circuit for a x10 passive probe)

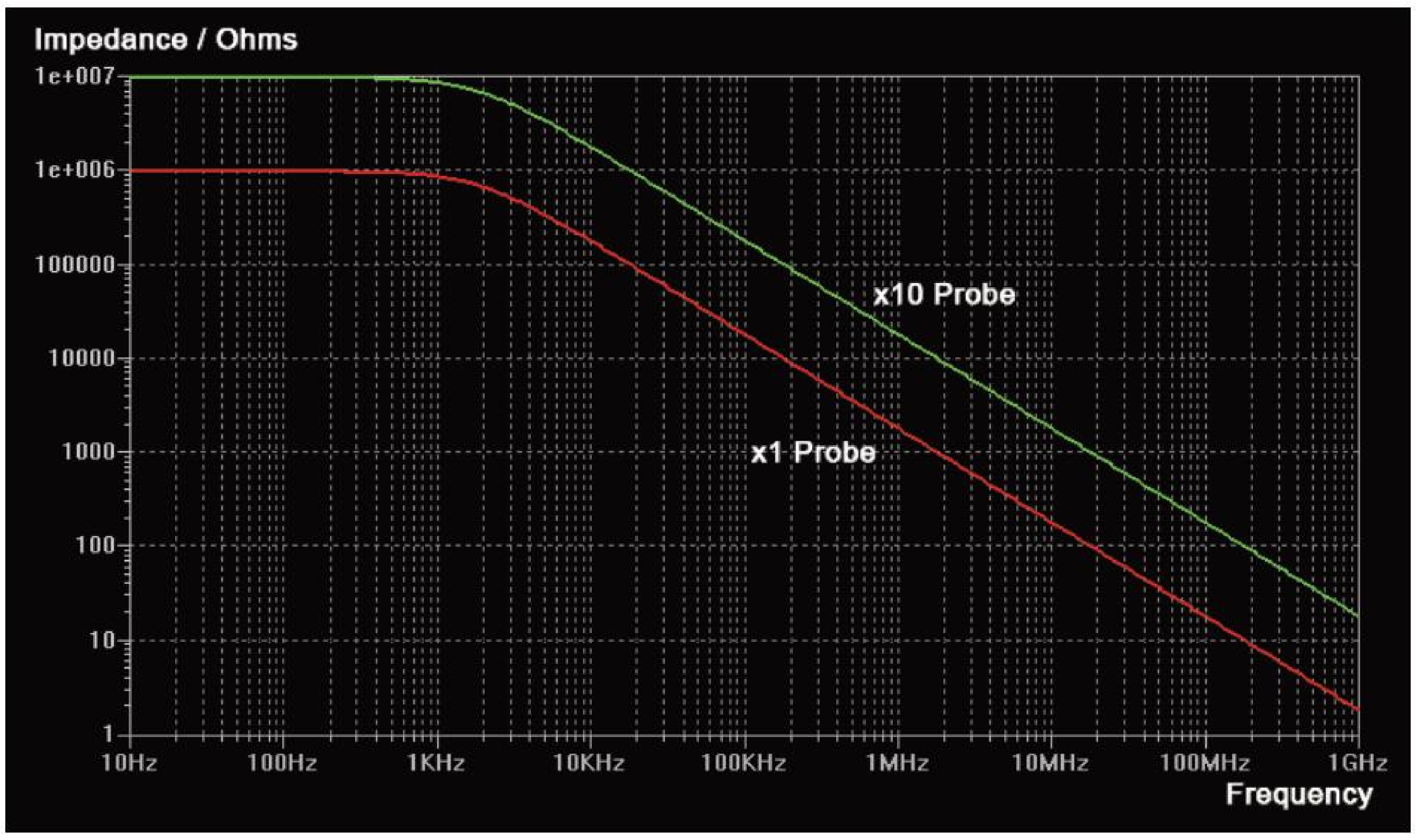


Fig.5. Variation of impedance of probe plus oscilloscope for x1 and x10 passive probes

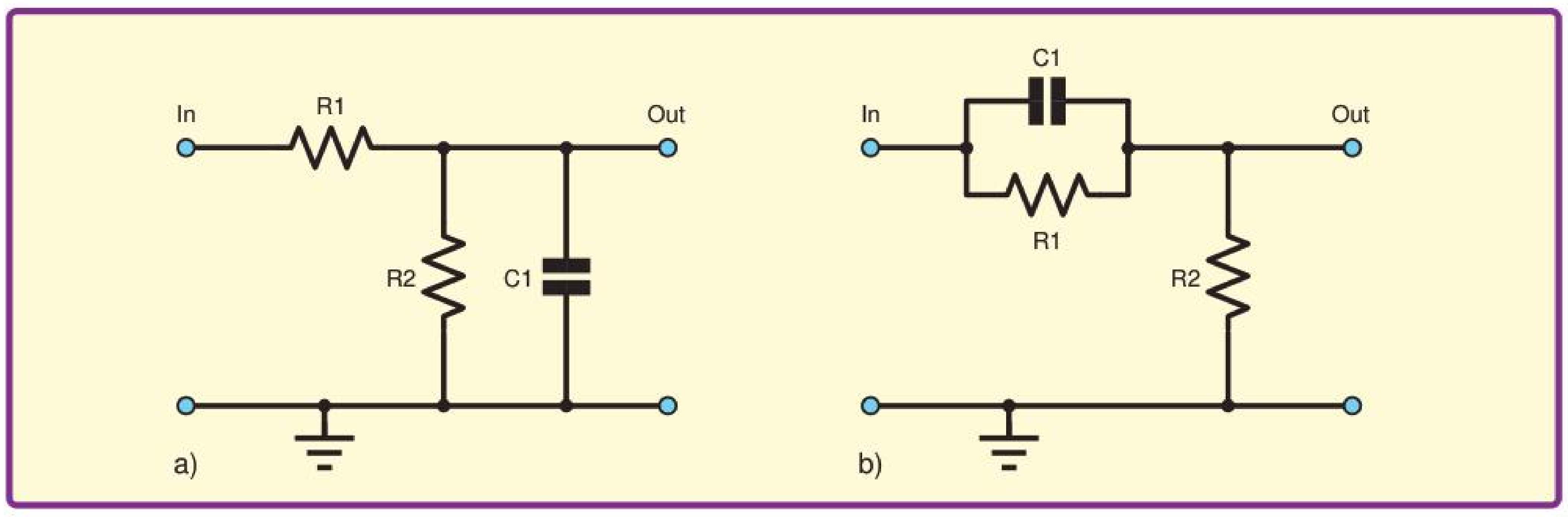

In
R1
Out
R2
C1
a)
In
C1
R1
Out
R2
b)

Fig.6. a) Low-pass circuit and b) high-pass circuit

a x1 probe across all frequencies. The probes have their full DC impedance of 1MΩ (x1) and 10MΩ (x10) at frequencies below about 1kHz, after that the impedance decreases steadily with increasing frequency.

Compensation

Fig.6 shows a couple of RC circuits that have (a) low-pass and (b) high-pass filter characteristics. For the circuit in Fig.6a, at DC and very low frequencies the circuit acts as potential divider with the attenuation set only by the resistor ratio. As frequency increases the effective resistance of the capacitor C1 decreases, increasing the attenuation. At very high frequencies the effective resistance of C1 tends towards zero and the output signal becomes close to zero. We have a low-pass function.

For the circuit in Fig.6b, at DC and very low frequencies the circuit also acts as potential divider, again with the attenuation set by the resistor ratio. As frequency increases the effective resistance of the capacitor C1 decreases, bypassing R1 and therefore increasing the output signal. At very high frequencies the effective resistance of C1 tends towards zero and the output signal becomes close to the input. We have a high-pass function.

As can be seen in Fig.4, the combination of a x10 probe and an oscilloscope input is similar to a combination of the circuits in Fig.6a and 6b (see Fig.7). This circuit can behave as either a high-pass or low-pass filter, depending on the relative values of the components. However, if certain combinations of the values are used then the high-pass and low-pass tendencies exactly match and the circuit has a flat frequency response. The condition required for this to happen (in the circuit in Fig.7) is R1×C1 = R2×C2. Under this condition the ratio of the impedance of the parallel combination of R1 and C1 to the impedance of the parallel combination of R2 and C2 is constant, so the potential divider attenuation is constant.

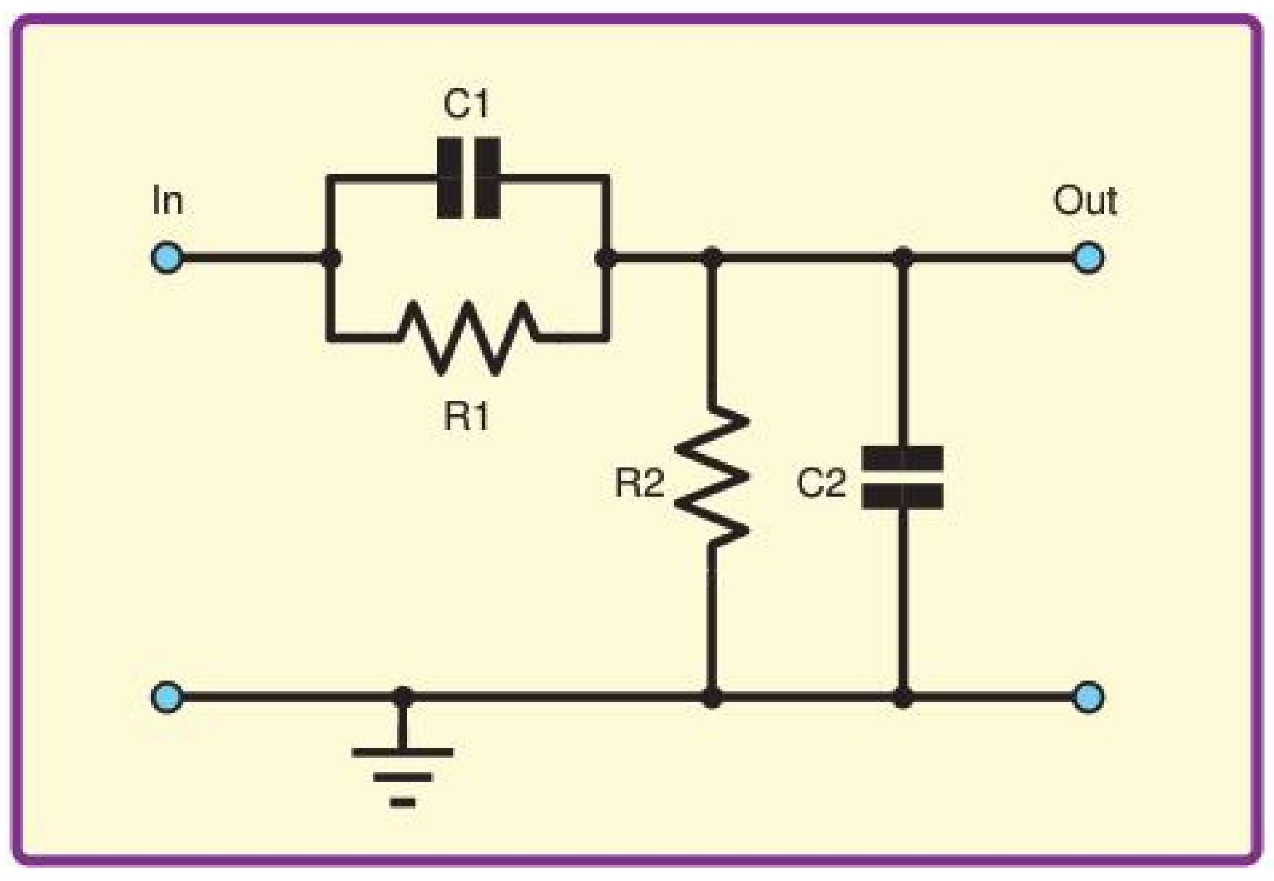

C1
In
Out
R1
R2
C2

Fig.7. RC circuit formed by probe and oscilloscope input

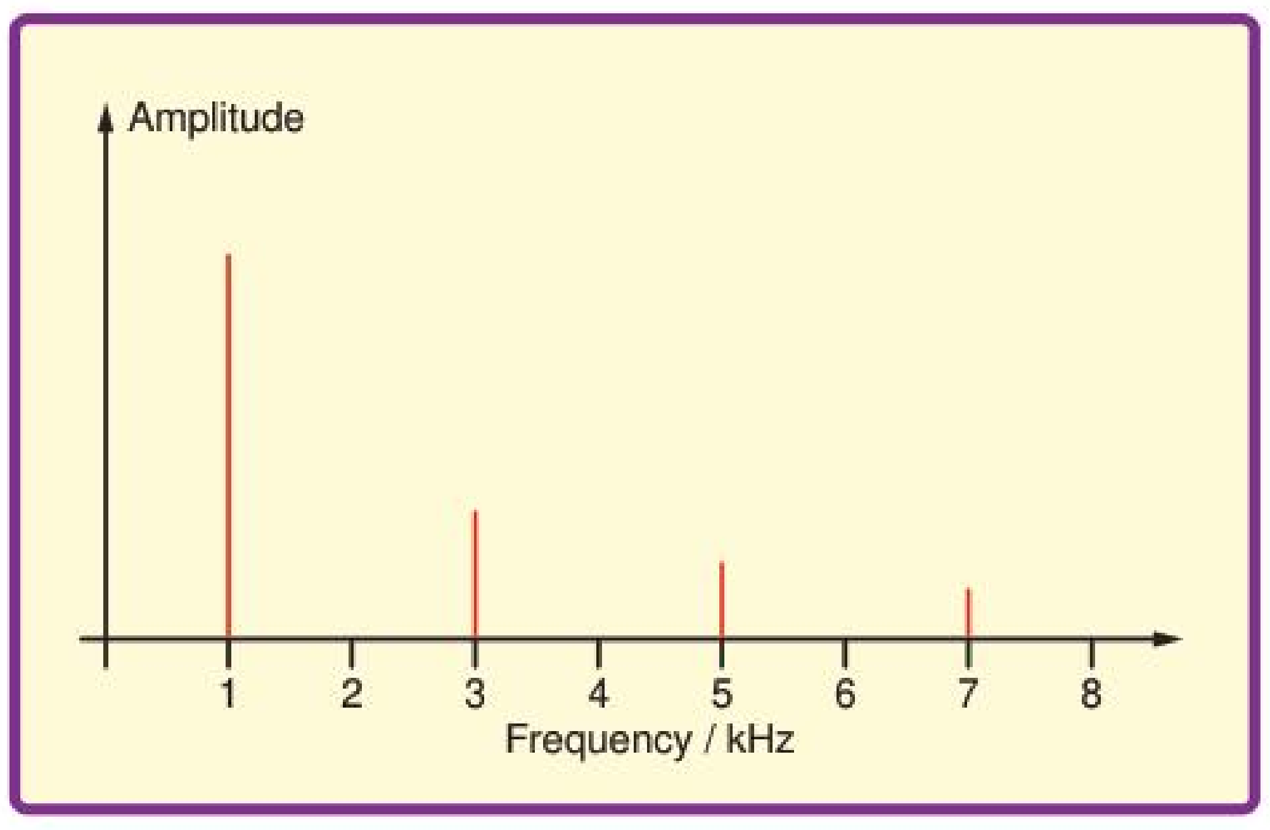


Fig.8. Spectrum of a 1kHz square wave

If the only waveforms we looked at with an oscilloscope were sinewaves then a flat frequency response would be desirable because it would facilitate accurate amplitude measurement across the frequency range. Other waveforms are more complex and contain components at multiple frequencies. For example, the relative amplitudes of the frequencies present in a 1kHz square wave are shown in Fig.8. For these signals the impact of a non-flat frequency response is more than just a straightforward measured amplitude attenuation. If the frequency response of a circuit is not flat it will change the relative amplitude of the various frequency components and therefore change the shape of the waveform. In the case of an oscilloscope the shape of the waveform seen will be distorted with respect to the actual signal.

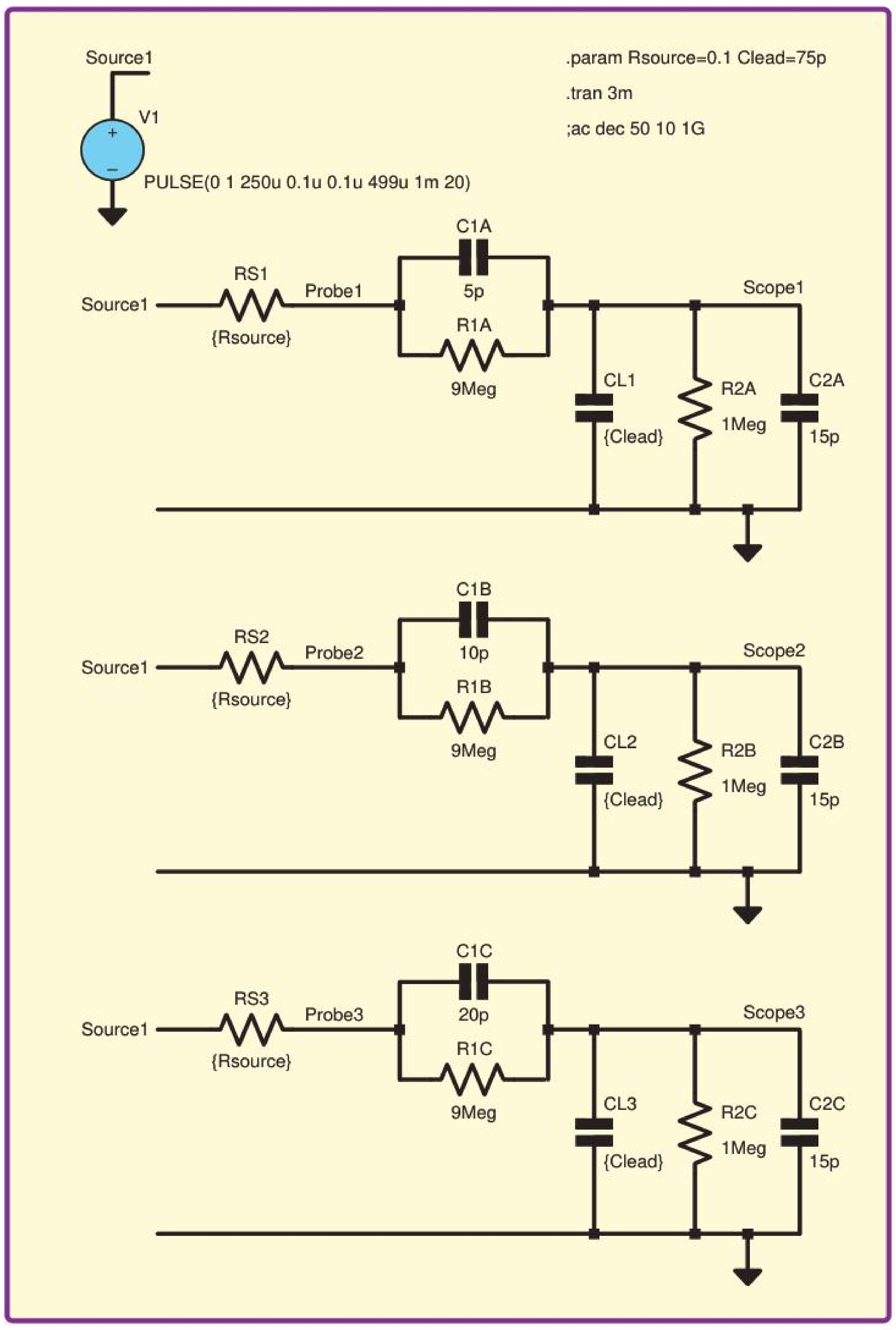

Source1
V1
PULSE(0 1 250u 0.1u 0.1u 499u 1m 20)
.param Rsource=0.1 Clead=75p
.tran 3m
;ac dec 50 10 1G
C1A
5p
RS1
{Rsource}
Source1
Probe1
R1A
9Meg
Scope1
CL1
{Clead}
R2A
1Meg
C2A
15p
C1B
10p
RS2
{Rsource}
Source1
Probe2
R1B
9Meg
Scope2
CL2
{Clead}
R2B
1Meg
C2B
15p
C1C
20p
RS3
{Rsource}
Source1
Probe3
R1C
9Meg
Scope3
CL3
{Clead}
R2C
1Meg
C2C
15p

Fig.9. LTSpice simulation schematic for comparing effect of compensation capacitor values

Due to manufacturing variations, changes in conditions, aging and the possible need to use the same probes on multiple oscilloscopes, the values of the capacitance in the scope probe, leads and scope inputs cannot be manufactured to always achieve the perfect balance (R1×C1 = R2×C2 in Fig.7) required for a flat frequency response. For this reason, x10 probes have a variable capacitance, which can be adjusted (typically using a small screwdriver) to achieve balance. This is referred to as probe compensation. Note that x1 probes do not have the adjustment facility because they do not have the additional circuitry in the probe. For x1/x10 switchable probes, the adjustment point is usually in the probe itself (as shown in Fig.4), but either capacitance (C1 or C2 in Fig.7) can be adjusted to achieve balance. Higher quality, higher frequency x10-only probes tend to have the adjustment in a small box right next to the connector, which plugs into the oscilloscope.

The usual way to make probe compensation adjustments is to connect the oscilloscope to a square wave signal with fast edges and adjust for minimum distortion of the displayed waveform. The oscilloscope may provide a suitable signal for this purpose. To illustrate this we can use the LTSpice simulation schematic shown in Fig.9. The simulation uses three copies of the x10 probe and oscilloscope input circuit from Fig.4 with different capacitor values. The ideal value for C1 is equal to (R2×C2)/R1 = (1MΩ × (75 +15)pF)/9MΩ = 10pF, which is used on the middle schematic (scope2 signal), the others are too low (5pF, scope1) and too high (20pF, scope 3). The results of the simulation showing the effect on the shape of the square wave are given in Fig.10.

Transmission line

For DC and relatively low frequencies we can consider the two ends of a wire or cable to be electrically at the same point in the circuit. At the scale of test leads used in the lab, any standard copper wire is likely to have such low resistance that the two ends can be considered as a short circuit most of the time. If we are dealing we very high currents we might have to worry about the resistance, but that certainly does not apply to an oscilloscope lead. We do need to consider the capacitance of the lead (the parallel conductors form a capacitor), as we did in the equivalent circuits discussed above. In some cases, particularly when dealing with fast changing signals the lead inductance may be of importance too.

For high frequencies and relatively long wires, there is a point where we can no longer consider the two ends as a short circuit, single capacitance or simple resistor/capacitor/inductor combination. We have to consider the electromagnetic fields created by the signal and think of it propagating down the wire as a wave. This is more like the way in which we think of a radio transmission, except the signal is guided down the wire rather than travelling through free space. When we think of wiring in this way we are dealing with what are known as 'transmission lines'.

As a rule of thumb, we have to use transmission lines rather than basic circuit theory when the length of a connection is more than about a tenth the wavelength of the signal. The wavelength (λ) is given by $\lambda = c/f$, where c is the speed of the wave and f is the frequency. We often think of electromagnetic waves travelling at the 'speed of light' (3×10^8m/s), but this applies to propagation through a vacuum – in cables the waves may travel more slowly. For a coax cable with a wave velocity of about half light-speed (1.5×10^8m/s) we need to consider transmission line effects for lead lengths of about 1.5m or more at 10MHz – certainly within the range of lead lengths and frequencies relevant to oscilloscopes. At higher frequencies, or with longer cables, transmission line effects become more relevant.

Imagine a narrow channel with water in it (like a canal). Create ripples at one end and it they will travel down the channel. Imaging the far end is blocked with a solid wall. What happens? The ripples reflect off the wall and travel back up the channel, creating interference patterns as they interact with the incoming ripples. The same thing happens with electrical signals in transmission lines. Now imagine a wider water channel connecting to a narrower one. This also creates reflections and interference, although some of the original waves will continue down the second channel. In electrical terms this is analogous to conductor mismatch – connecting two cables or circuits with different transmission line characteristics will cause signal reflections and not all of the signal will go straight to the load.

For fixed circuits the solution (way to prevent reflections) is to match all the connections in terms of transmission line characteristics. Specifically, the characteristic impedance of the line (Z_0) defines this. The only other parameter required to define an ideal line is the length, which can be stated in terms of the delay (time taken for the wave to travel its length). Coaxial cables are not perfect transmission lines, but for most purposes they are close. It may seem sensible to use a standard coax as a scope lead, but the problem is the circuit configuration is not fixed, so it is not possible to always have a matched connection. Mismatches causes reflections, which will either cancel or reinforce the original wave from the signal being measured. The effect of this is that the measured signal amplitude (at high frequencies) will vary rapidly with frequency as the reflected waves change between cancellation and reinforcement.

The solution is to use a lossy transmission line – which is why scope leads use resistive conductors, as mentioned by ***741*** and ***zeitghost***. We can simulate the two situations in LTspice as it provides both ideal and lossy transmission line components. Fig.11 shows the setup for this simulation and Fig.12 the results. The lossy transmission line in LTspice is specified in terms of its length and R, C and L values per unit length. The resistance value of 200Ω is about right for a probe lead, but is not meant to relate to a specific product. The results in Fig.12 show that the lossy line provides a flat frequency

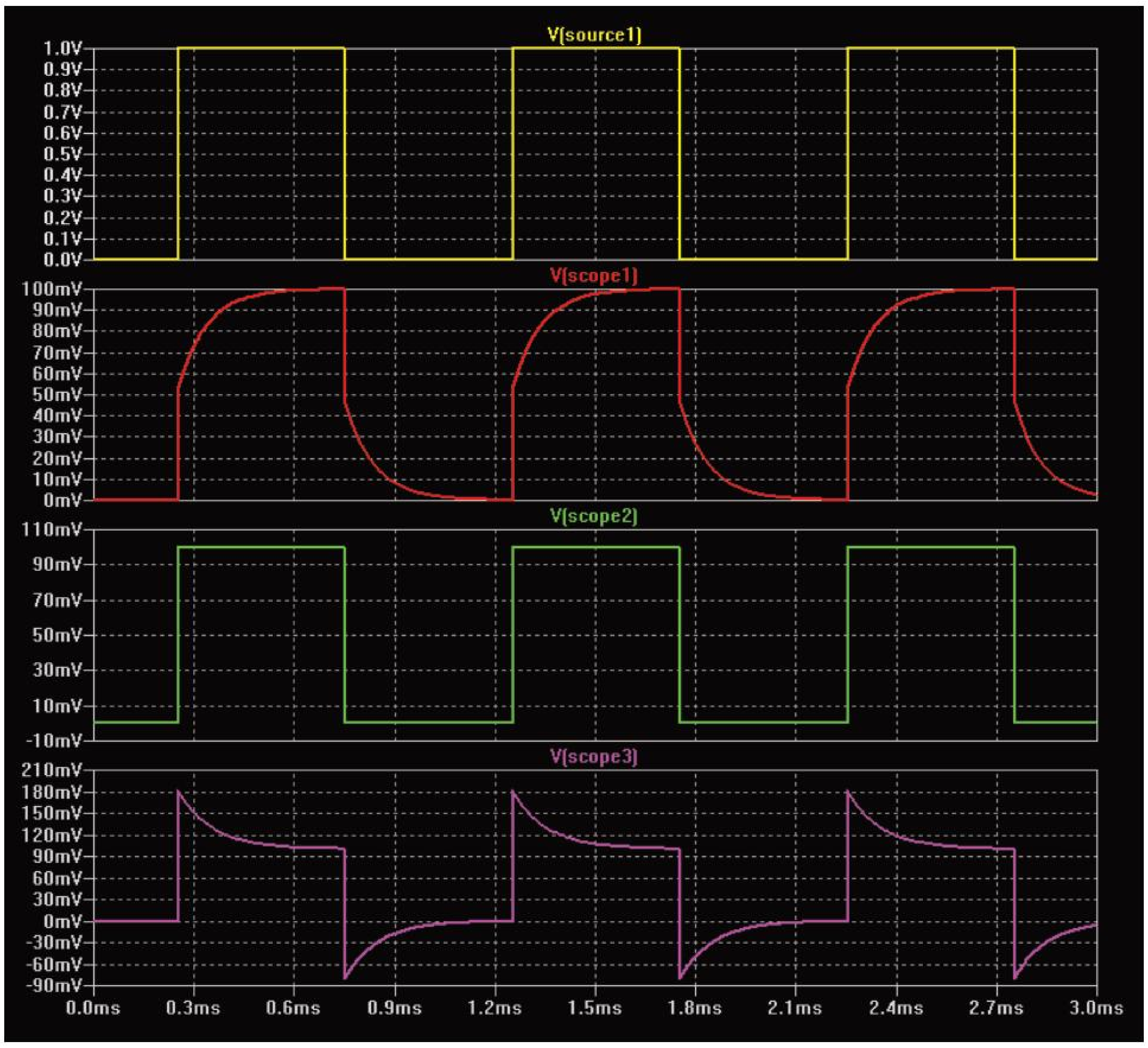


Fig.10. Results from the simulation shown in Fig.9. The upper trace is the input square wave, the second trace is with C1 too small, the third trace is for the ideal value of C1 (probe correctly compensated) and the bottom trace is for C1 too large

response, but the ideal line has a wildly varying response due to reflection effects.

Use of the lossy transmission line explains the lower bandwith of the probe in x1 mode, which ***simonbond*** asked about. The resistance of the lossy line combined with circuit capacitance result in a low-pass filter, even when the probe is driven directly from a low-impedance source (little loading effect). The x10 probe greatly reduces the impact of the line resistance on the overall frequency response – the probe has attenuation but much higher bandwith. Fig.13 and 14 show a spice simulation, which compares x1 and x10 probes with a lossy transmission line probe lead.

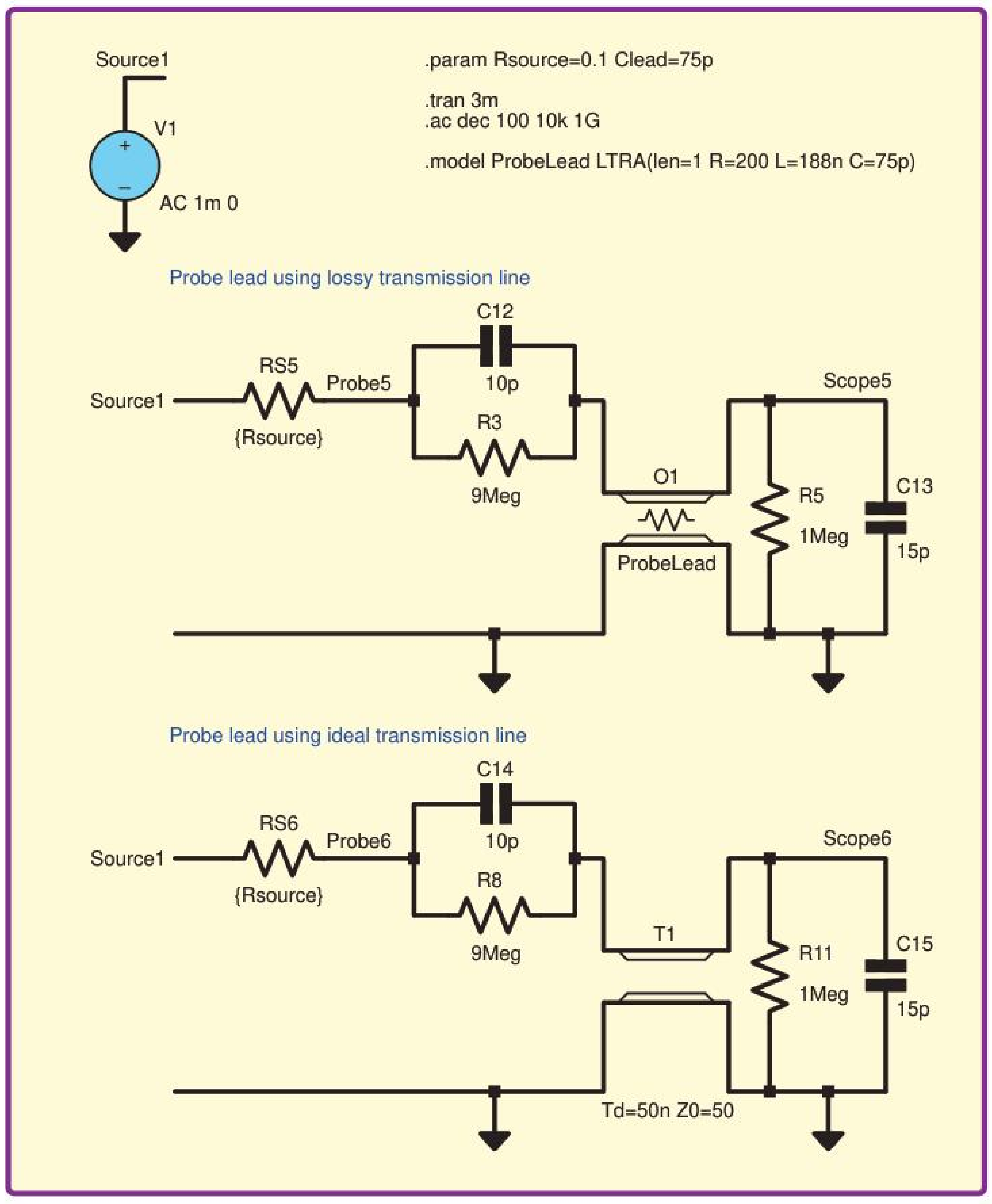

Source1
V1
AC 1m 0
.param Rsource=0.1 Clead=75p
.tran 3m
.ac dec 100 10k 1G
.model ProbeLead LTRA(len=1 R=200 L=188n C=75p)
Probe lead using lossy transmission line
C12
10p
RS5
Probe5
Source1
{Rsource}
R3
9Meg
O1
ProbeLead
Scope5
R5
1Meg
C13
15p
Probe lead using ideal transmission line
C14
10p
RS6
Probe6
Source1
{Rsource}
R8
9Meg
T1
Td=50n Z0=50
Scope6
R11
1Meg
C15
15p

Fig.11. LTSpice simulation schematic for comparing effect of transmission line properties.

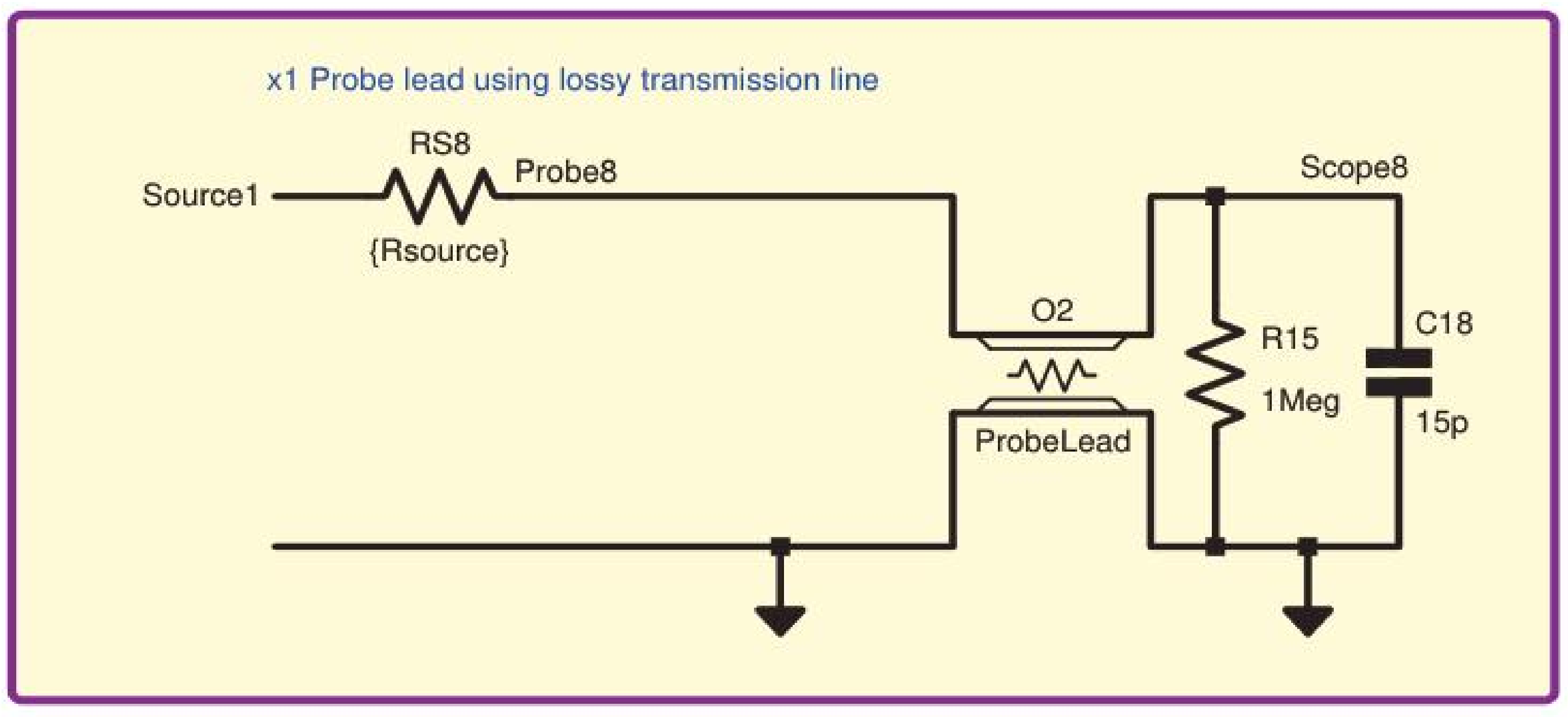

x1 Probe lead using lossy transmission line
Source1
RS8
Probe8
{Rsource}
O2
ProbeLead
Scope8
R15
1Meg
C18
15p

Fig.13. LTSpice simulation schematic for x1 probe with lossy transmission line. This is added to the schematic in Fig.11

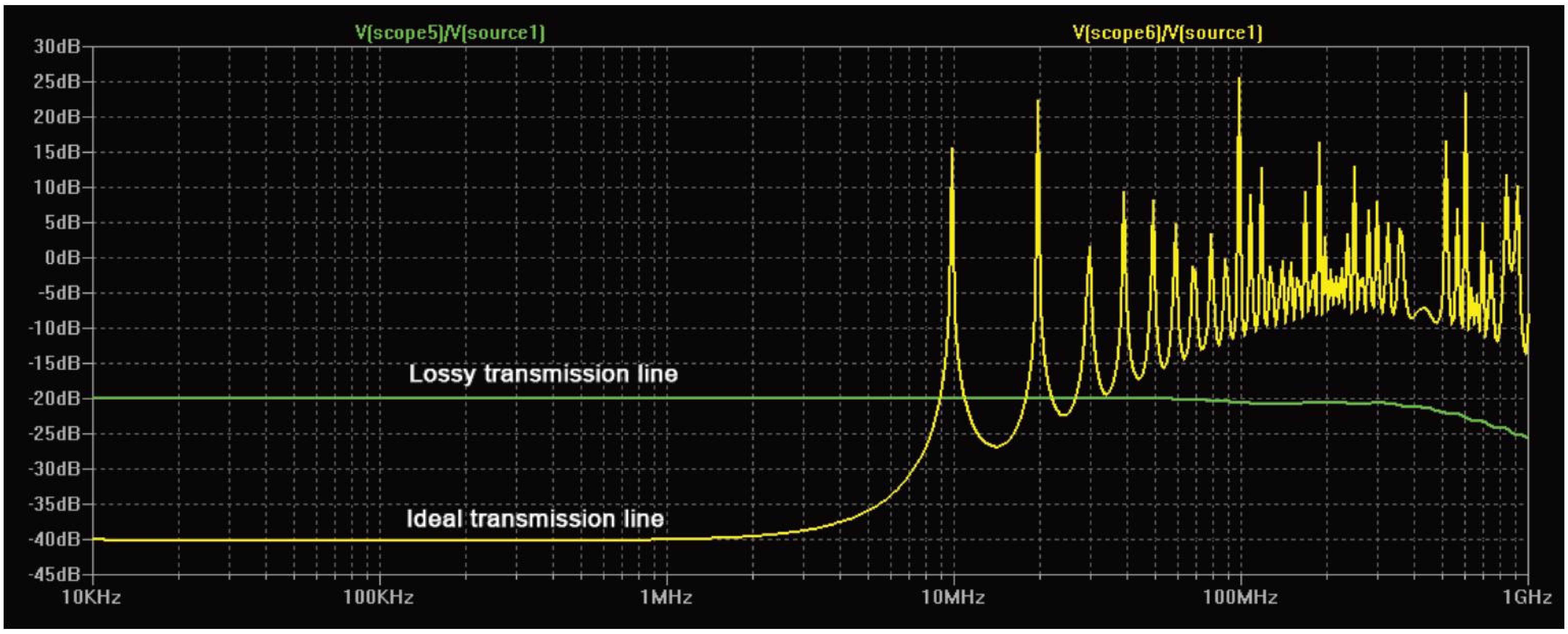


Fig.12. Results from the simulation shown in Fig.11. Comparison of frequency response of x10 probe with lossy and ideal transmission line leads

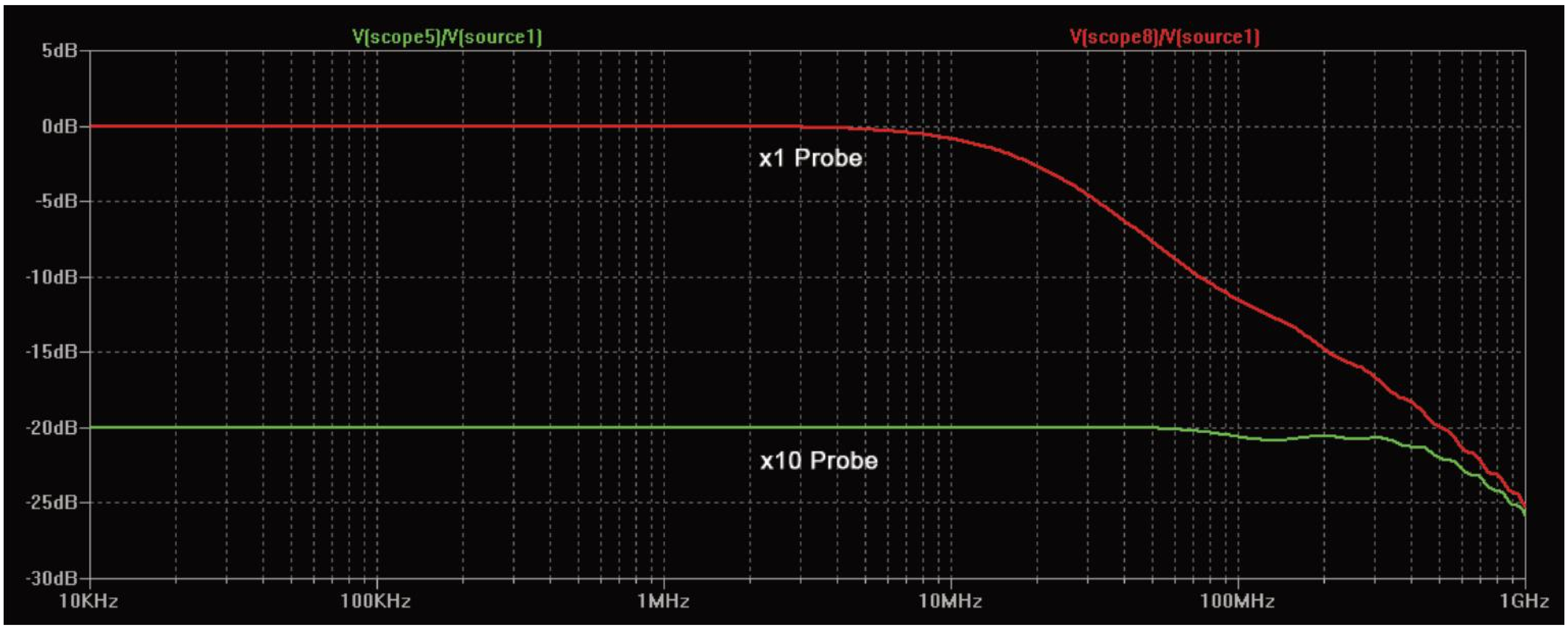


Fig.14. Results from the simulation shown in Fig.13. Comparison of frequency response of x1 and x10 probes with a lossy transmission line lead

PIC18F "K40" MCUs feature Intelligent ADC with Filtering and Signal Analysis Capabilities

8-bit PIC® MCUs are ideal for Touch and Signal Conditioning

MICROCHIP
PIC18F67K40
MICROCHIP
PIC18F65K40
MICROCHIP
PIC18F24K40
MICROCHIP
PIC18F26K40
MICROCHIP
PIC18F24K40

The Core Independent Peripherals (CIPs) in Microchip's PIC18F "K40" family of 8-bit PIC® MCUs support filtering and signal analysis for advanced touch and signal-conditioning applications.

Among the intelligent analog CIPs is an Analog-to-Digital Converter with Computation (ADC2) for averaging, filtering, oversampling and automatic threshold comparison. The MCUs also integrate safety-critical CIPs and hardware PWMs with multiple communication interfaces and generous on-chip Flash and EEPROM. These features, combined with 5V operation, enable the PIC18F "K40" family to increase design flexibility whilst also reducing system cost.

microchip DIRECT
www.microchipdirect.com

MICROCHIP

www.microchip.com/EUPIC18FK40

The Microchip name and logo, the Microchip logo, MPLAB and PIC are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries. All other trademarks mentioned herein are the property of their respective companies. © 2016 Microchip Technology Inc. All rights reserved. DS30010138A. MEC2125Eng11/16

AUDIO OUT

By Jake Rothman

MX50 power amplifier kit – Part 2

Last month, I introduced the excellent MX50 power amplifier kit. This month, it's time to look at the power supply, some possible improvements and testing.

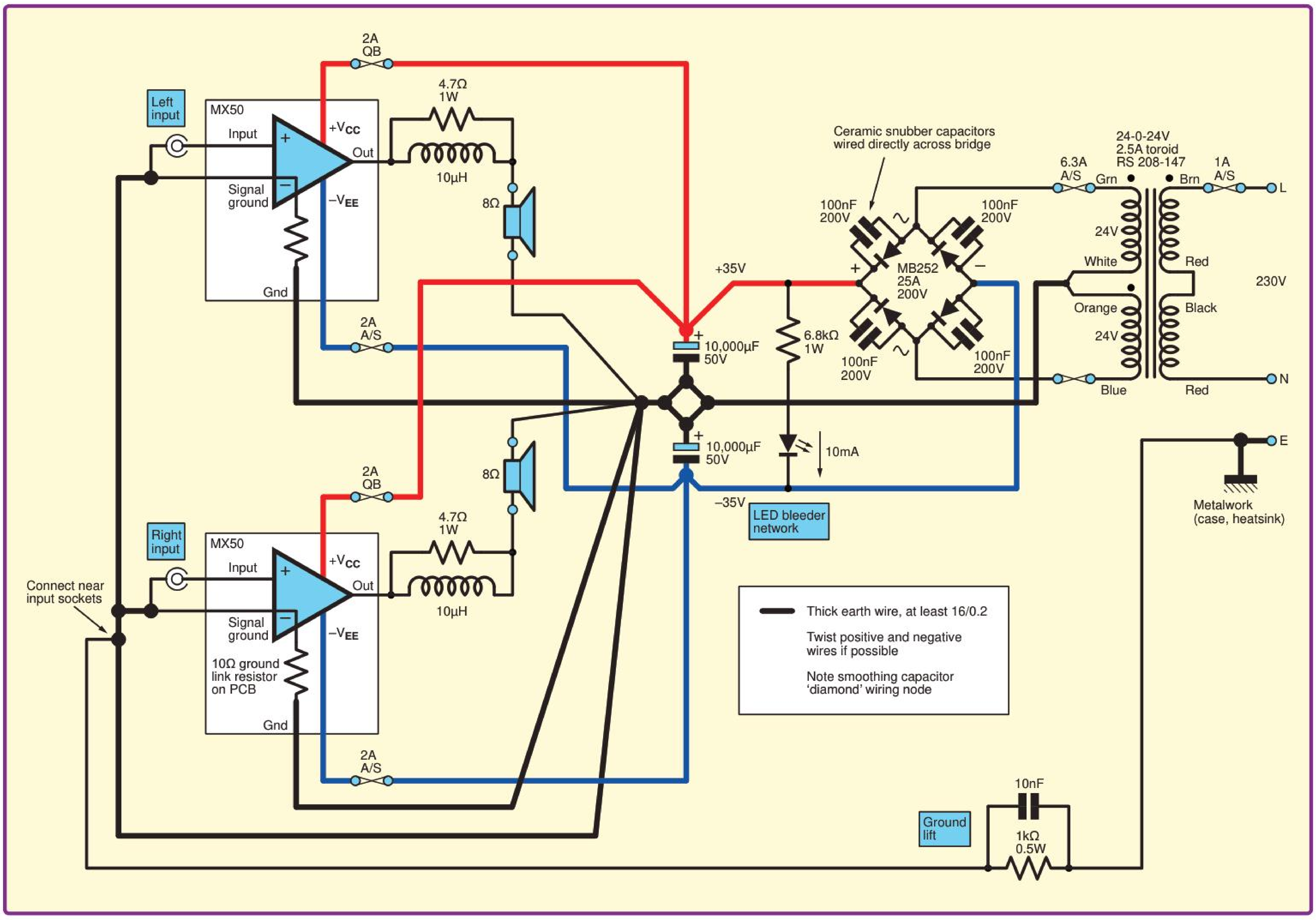
Power supply and wiring

The dual power supply is the same as a single-rail system except there are two smoothing capacitors with an extra node for the negative rail, as shown in Fig.8. The kit provides a ferrite bead to link the signal ground and dirty ground on the board to reduce RF interference. Since the hum loop problem in stereo amps is low frequency, this would not be effective and a 10Ω resistor is inserted. A photo of the stereo amplifier test bed shown in Fig.9 illustrates a recommended physical arrangement that gives no hum. If the transformer used has a significant hum field, use the heatsink as a screen between it and the boards.

Improvements

Since there is no VAS buffer, the gain of the VAS transistor TR9 is important. The supplied 2N5551 transistors have an H_{fe} of around 130. The loading on the input stage and the overall open-loop gain is reduced by the inclusion of an emitter resistor (R18). An audiophile Japanese transistor, such as the 2SC3071 (H_{fe} = 600) could be used here, and may improve HF distortion. It made no difference at 1kHz. C3 could be replaced by a non-polarised electrolytic to reduce LF distortion. The most important improvement would be to add an I_q adjustment. A 50kΩ trimmer in series with an 8.2kΩ can be wired in parallel across R17. Later, this can be replaced with a fixed resistor. In my case, I used 22kΩ for one channel and 18kΩ for the other.

A suggested short-circuit protection circuit is shown in Fig.10. It senses the voltage across the emitter resistors and shuts down the amplifier by removing the bias from the current sources. It also



2A
QB
4.7Ω
1W
Left input
MX50
Input
+VCC
Out
10µH
Signal ground
–VEE
8Ω
Gnd
2A
A/S
+35V
Ceramic snubber capacitors wired directly across bridge
100nF 200V
100nF 200V
MB252 25A 200V
100nF 200V
100nF 200V
6.8kΩ 1W
10,000µF 50V
10,000µF 50V
10mA
–35V
LED bleeder network
6.3A A/S
Grn
24-0-24V 2.5A toroid RS 208-147
1A A/S
Brn
L
24V
White
Red
230V
Orange
Black
24V
Blue
Red
N
E
Metalwork (case, heatsink)
2A
QB
8Ω
4.7Ω
1W
Right input
MX50
Input
+VCC
Out
10µH
Connect near input sockets
Signal ground
–VEE
10Ω ground link resistor on PCB
Gnd
2A
A/S
Thick earth wire, at least 16/0.2
Twist positive and negative wires if possible
Note smoothing capacitor 'diamond' wiring node
10nF
Ground lift
1kΩ
0.5W

Fig.8. A suggested wiring diagram for all stereo dual-rail power amplifiers and entirely appropriate for the MX50. Remember to insert 10Ω ground-lift resistors in the FB1 position.

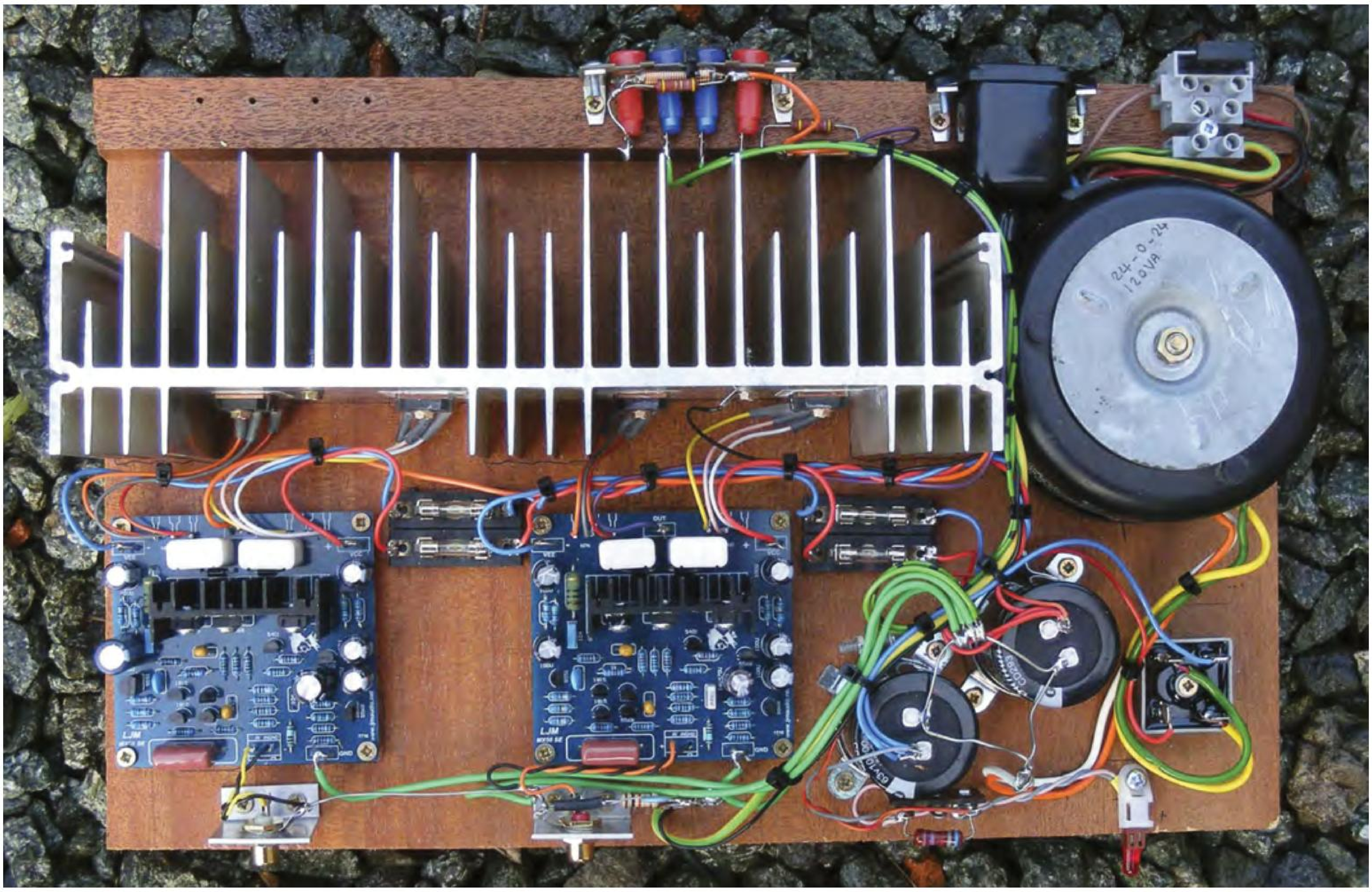

24-0-24
120VA

Fig.9. The completed MX50 amplifier test bed built on a wooden board. This helps with evaluating optimum layout for a given case, since it is much easier to chop and change screwing into wood rather than drilling metal.

provides a switch-on delay, useful for suppressing thumps from a proceeding circuit. This can be assembled on a small piece of stripboard and retrofitted to the amp, as shown in Fig.11. With this particular amplifier configuration it's best to make the positive rail fuse smaller than the negative rail fuse, because when it blows the amp is turned off with no offset. If only the negative rail fuse blows, a full positive offset occurs. If a 1N4004 diode is connected from V– to ground this offset reduces to 3V and the capacitors are protected from reverse polarisation. I used a 2A quick-blow fuse for the positive and a slow-blow type for the negative. An already-very-low hum can be reduced below the noise floor by increasing C9 to 470µF. The hard-wired amp shown with the inputs shorted had 2.5mV of noise on the outputs, one of the lowest I've ever measured.

A debatable 'improvement' is to use lateral MOSFETs, such as the 2SJ162 and 2SK1058, which can survive momentary shorts – replace TR12 and TR13 respectively. Gate resistors will have to be added and the bias voltage ramped up. The distortion will go up, the output will go down and they cost five-times more than bipolar transistors. However, the reliability can be around five-times better according to *The Audiophile's Project Sourcebook* by Randy Slone.

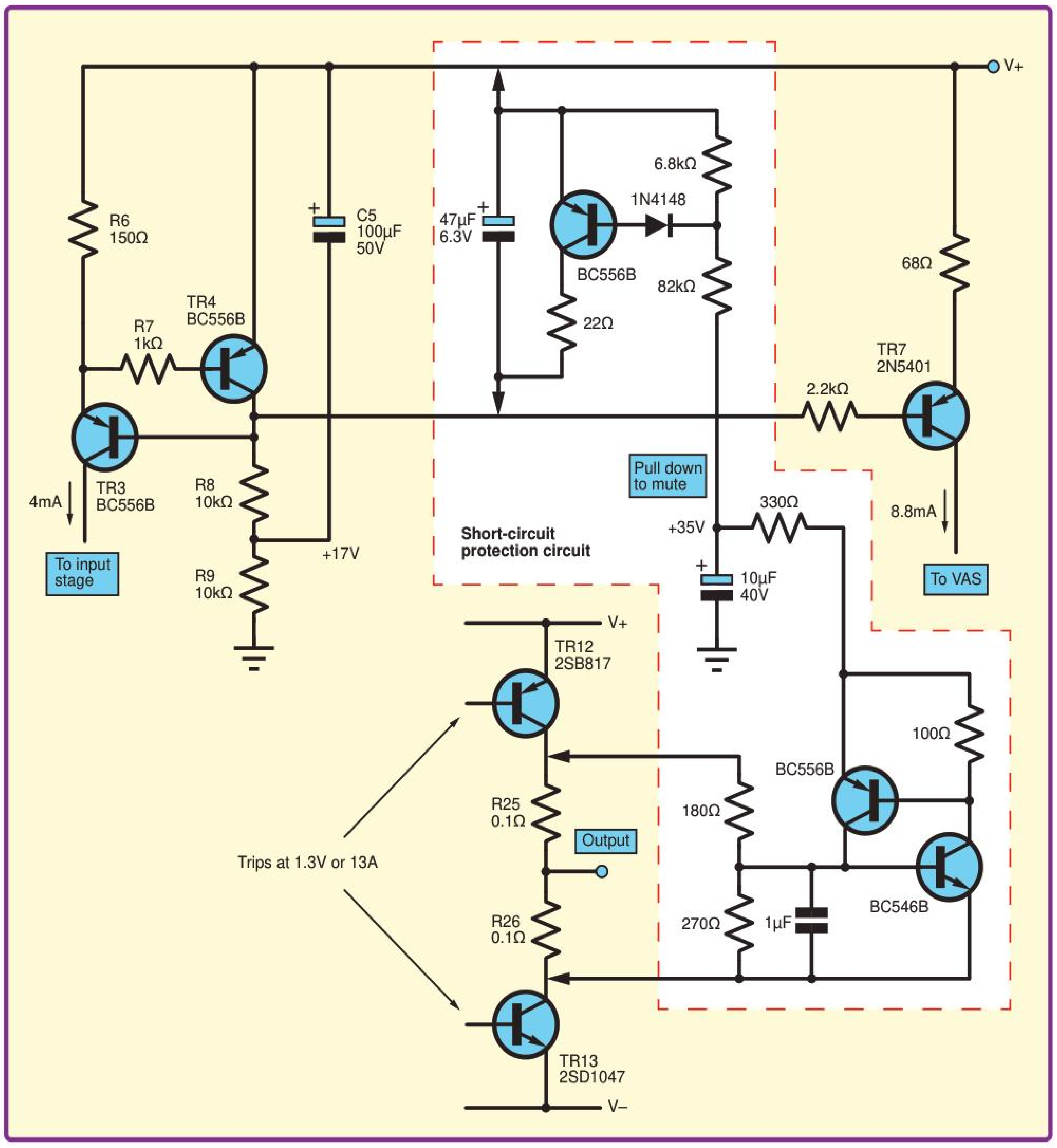

V+
R6
150Ω
C5
100µF
50V
47µF
6.3V
6.8kΩ
1N4148
BC556B
82kΩ
22Ω
68Ω
TR7
2N5401
2.2kΩ
R7
1kΩ
TR4
BC556B
TR3
BC556B
4mA
R8
10kΩ
R9
10kΩ
+17V
To input stage
Pull down to mute
+35V
330Ω
10µF
40V
Short-circuit protection circuit
8.8mA
To VAS
V+
TR12
2SB817
R25
0.1Ω
Output
Trips at 1.3V or 13A
R26
0.1Ω
TR13
2SD1047
V–
180Ω
270Ω
1µF
100Ω
BC556B
BC546B

Fig.10. A suggested short-circuit protection system, which is not too complicated to add. It is inspired by the system used on the Mission Cyrus 1 amplifier.

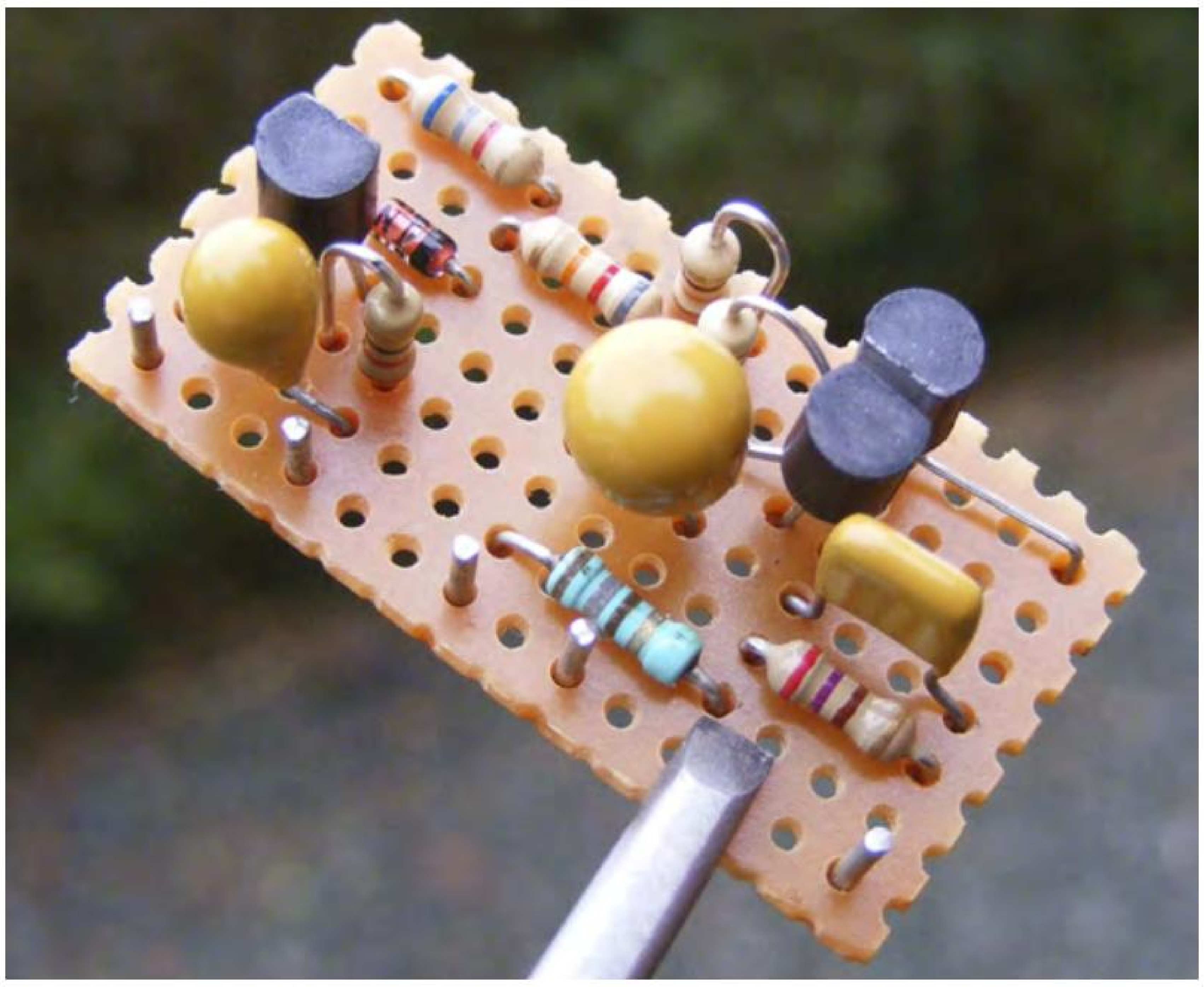


Fig.11. The short-circuit protection circuit is easily built on stripboard.

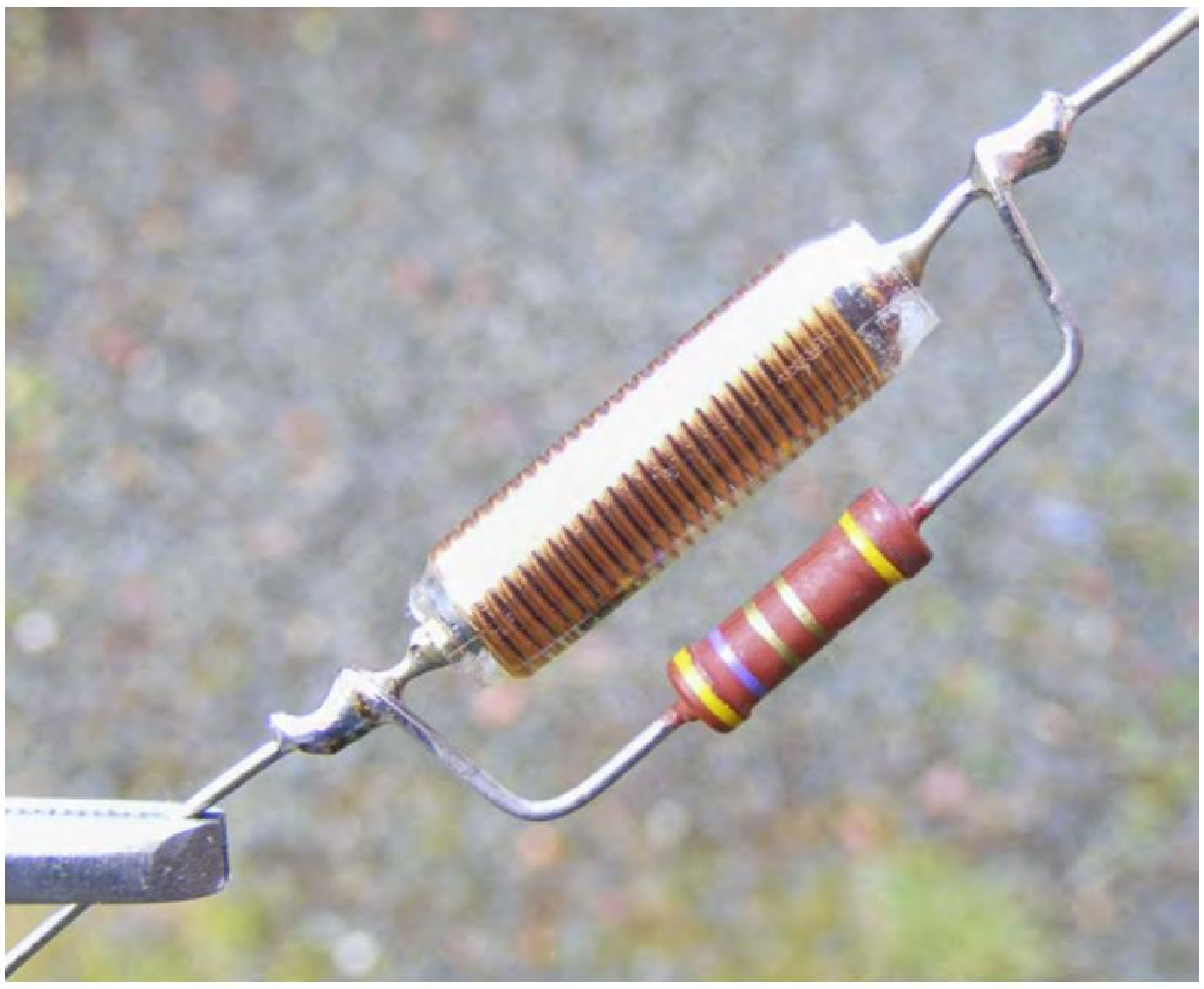


Fig.12. An LC network should be inserted at the output pin if driving high capacitance loads, such as fancy plaited speaker cable.

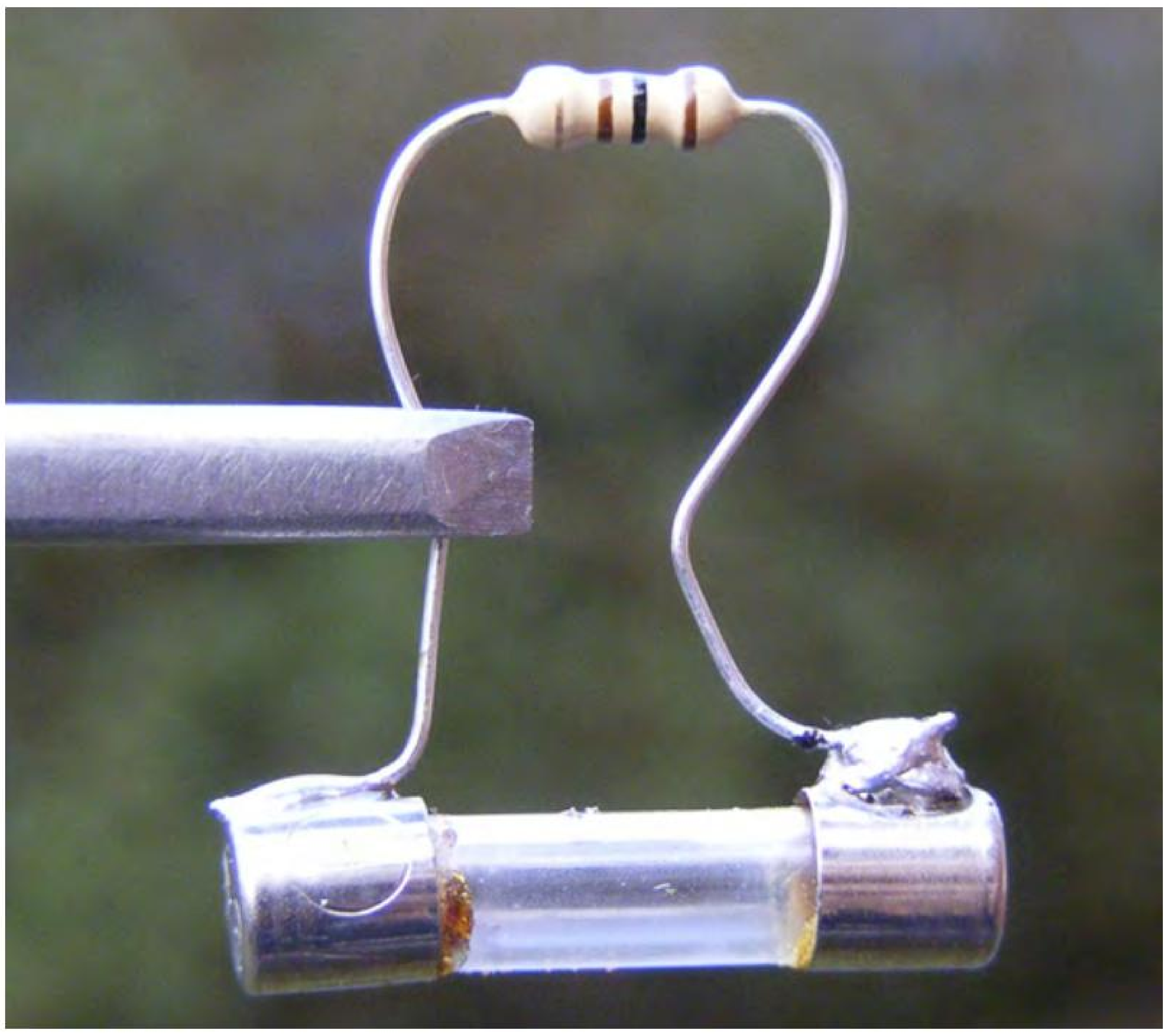


Fig.13. One of my special power amplifier test techniques is to solder 100Ω resistors across blown fuses and insert these into the fuse holders for current limiting with added smoke signalling.

There is no output inductor to prevent oscillation with long high-capacitance speaker leads, but this can easily be added. The 10µH inductor with a 4.7Ω resistor in parallel, as shown in Fig.12, will suffice.

Voltage variations

A safe maximum-rail voltage for the transistors supplied would be ±37.5V, which would equate to a transformer of 28V-0-28V. These are hard to obtain and the nearest available would be 25V-0-25V. With a 24-0-24V 2.5A 120VA transformer and adequate heatsinking, the amp delivered 58$V_{pk\text{-}pk}$ or 52.5W_{rms} into 8Ω at 1kHz. The rail voltage at this power was ±31.5V, meaning there was a total loss of 5V. 1.6V of this was across the decoupling resistors R19 and 20. If high-power 4Ω running is contemplated, it would be worthwhile doubling-up the output transistors. If you must use 4Ω speakers, drop the transformer voltage to 22V-0-22V. Remember, distortion with class AB amplifiers triples going from 8Ω to 4Ω loads. If lower power, say around 20W into 8Ω is acceptable, cheap transistors such as TIP3055s, BC182s, BD139s and their respective complements could be used with 18-0-18V or 15-0-15V transformers. This would be a good starting point for students and beginners.

Testing

Discrete transistor power amplifiers are notoriously intolerant of errors, often resulting in instant destruction of the output and driver transistors. With no current limiting, a PCB can even catch fire. Use a power supply with a current limit set to 300mA for initial testing if available, or put 100Ω resistors in series with the power lines. I solder these resistors to blown 20mm fuses, as shown in Fig.13, which can then be easily inserted/removed.

Never connect a load to a transistor amplifier when powering up for the first time. Use small fuses in the amplifier power supplies, say 100mA or resistors, and if they don't blow, check for DC off-set on the output, which should be less than 20mV.

Next, check the I_q is correct, it should be just over 15mA. This equates to 3mV across the emitter resistors, easily measured by putting the meter probes onto the output transistor collector metal tabs. Note that this drifts down as the amplifier warms up. All the MX50s I measured gave values of around 1.2 to 1.5mV and therefore had too low an I_q. Visible crossover glitches were present at 11kHz and above. These disappeared when I trimmed the I_q. Note these could only be seen on an analogue scope, you won't see them on a standard digital unit with 8-bit resolution.

Next, connect a signal generator set to 1kHz sinewave on the input and hook up an oscilloscope to the output and check for oscillation and distortion. If all is well, bring up to clipping. If this is okay, connect a load resistor and allow the output to just clip briefly, again checking for problems. Read off the peak-to-peak voltage to calculate the power output. Finally, test with music and other difficult signals.

It's a bargain!

For those looking for a low-cost entry into high-quality discrete amplification that beats the sound quality of chips, and is almost as good as the Self design, the MX50 is ideal. I've just bought 10 for my audio engineering BSc students. Luckily, they have proper dual-rail bench power supplies that will shut down if there's a short, so hopefully there will be no fireworks.

HP 34401A Digital Multimeter 6 ½ Digit

HP 54600B Oscilloscope Analogue/Digital Dual Trace 100MHZ

MARCONI 2955B Radio Communications Test Set

FLUKE/PHILIPS PM3092 Oscilloscope 2+2 Channel 200MHZ Delay TB, Autoset etc

LAMBDA GENESYS	PSU GEN100-15 100V 15A Boxed As New	£325
LAMBDA GENESYS	PSU GEN50-30 50V 30A	£325
HP34401A	Digital Multimeter 6.5 digit	£275-£325
HP33120A	Function Generator 100 microHZ-15MHZ	£260-£300
HP53131A	Universal Counter 3GHZ Boxed unused	£500
HP53131A	Universal Counter 225MHZ	£350
HP54600B	Digital Oscilloscope 100MHZ 20MS/S	from £75
IFR 2025	Signal Generator 9kHz - 2.51GHZ Opt 04/11	£900
Marconi 2955B	Radio Communications Test Set	£800
R&S APN62	Syn Function Generator 1HZ-260KHZ	£195
Fluke/Philips PM3092	Oscilloscope 2+2 Channel 200MHZ Delay etc	£250
HP3325A	Synthesised Function Generator	£195
HP3561A	Dynamic Signal Analyser	£650
HP6032A	PSU 0-60V 0-50A 1000W	£750
HP6622A	PSU 0-20V 4A Twice or 0-50V 2A Twice	£350
HP6624A	PSU 4 Outputs	£350
HP6632B	PSU 0-20V 0-5A	£195
HP6644A	PSU 0-60V 3.5A	£400
HP6654A	PSU 0-60V 0-9A	£500
HP8341A	Synthesised Sweep Generator 10MHZ-20GHZ	£2,000
HP83731A	Synthesised Signal Generator 1-20GHZ	£1,800
HP8484A	Power Sensor 0.01-18GHZ 3nW-10uW	£75
HP8560A	Spectrum Analyser Synthesised 50HZ - 2.9GHZ	£1,250
HP8560E	Spectrum Analyser Synthesised 30HZ - 2.9GHZ	£1,750
HP8563A	Spectrum Analyser Synthesised 9KHZ-22GHZ	£2,250
HP8566B	Spectrum Analsyer 100HZ-22GHZ	£1,200
HP8662A	RF Generator 10KHZ - 1280MHZ	£750
Marconi 2022E	Synthesised AM/FM Signal Generator 10KHZ-1.01GHZ	£325
Marconi 2024	Synthesised Signal Generator 9KHZ-2.4GHZ	£800
Marconi 2030	Synthesised Signal Generator 10KHZ-1.35GHZ	£750
Marconi 2305	Modulation Meter	£250
Marconi 2440	Counter 20GHZ	£295
Marconi 2945	Communications Test Set Various Options	£2,500
Marconi 2955	Radio Communications Test Set	£595
Marconi 2955A	Radio Communications Test Set	£725
Marconi 6200	Microwave Test Set	£1,500
Marconi 6200A	Microwave Test Set 10MHZ-20GHZ	£1,950
Marconi 6200B	Microwave Test Set	£2,300
Marconi 6960B with	6910 Power Meter	£295

Tektronix TDS3012	Oscilloscope 2 Channel 100MHZ 1.25GS/S	£450
Tektronix 2430A	Oscilloscope Dual Trace 150MHZ 100MS/S	£350
Tektronix 2465B	Oscilloscope 4 Channel 400MHZ	£600
Cirrus CL254	Sound Level Meter with Calibrator	£40
Farnell AP60/50	PSU 0-60V 0-50A 1KW Switch Mode	£195
Farnell H60/50	PSU 0-60V 0-50A	£500
Farnell B30/10	PSU 30V 10A Variable No Meters	£45
Farnell B30/20	PSU 30V 20A Variable No Meters	£75
Farnell XA35/2T	PSU 0-35V 0-2A Twice Digital	£75
Farnell LF1	Sine/sq Oscillator 10HZ-1MHZ	£45
Racal 1991	Counter/Timer 160MHZ 9 Digit	£150
Racal 2101	Counter 20GHZ LED	£295
Racal 9300	True RMS Millivoltmeter 5HZ-20MHZ etc	£45
Racal 9300B	As 9300	£75
Black Star Orion	Colour Bar Generator RGB & Video	£30
Black Star 1325	Counter Timer 1.3GHZ	£60
Ferrograph RTS2	Test Set	£50
Fluke 97	Scopemeter 2 Channel 50MHZ 25MS/S	£75
Fluke 99B	Scopemeter 2 Channel 100MHZ 5GS/S	£125
Gigatronics 7100	Synthesised Signal Generator 10MHZ-20GHZ	£1,950
Panasonic VP7705A	Wow & Flutter Meter	£60
Panasonic VP8401B	TV Signal Generator Multi Outputs	£75
Pendulum CNT90	Timer Counter Analyser 20GHZ	£750
Seaward Nova	PAT Tester	£95
Solartron 7150	6 1/2 Digit DMM True RMS IEEE	£65
Solartron 7150 Plus	as 7150 plus Temp Measurement	£75
Solatron 7075	DMM 7 1/2 Digit	£60
Solatron 1253	Gain Phase Analyser 1mHZ-20KHZ	£600
Tasakago TM035-2	PSU 0-35V 0-2A 2 Meters	£30
Thurlby PL320QMD	PSU 0-30V 0-2A Twice	£160-£200
Thurlby TG210	Function Generator 0.002-2MHZ TTL etc Kenwood Badged	£65

STEWART OF READING

17A King Street, Mortimer, near Reading, RG7 3RS

Telephone: **0118 933 1111** Fax: **0118 9331275**

USED ELECTRONIC TEST EQUIPMENT

Check website **www.stewart-of-reading.co.uk**

CRICKLEWOOD ELECTRONICS

Established 1981

Frustrated with your supplier? Visit our component packed website for a vast range of parts - old and new, many unavailable elsewhere!

www.cricklewoodelectronics.com

1000's OF PRICES REDUCED!

Alternatively phone us on 020 8452 0161 with your requirements.

Visit our Shop, Call or Buy online at:

www.cricklewoodelectronics.com

020 8452 0161

Visit our shop at:
40-42 Cricklewood Broadway
London NW2 3ET

Get the answer you've been looking for

PICs?
Can anyone help me?
Problem sourcing software?
General Electronics chat
I Can help!

Vist the EPE Chat Zone

www.epemag.com

Ingenuity Unlimited

Our regular round-up of readers' own circuits

We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas must be the reader's own work and **must not have been published or submitted for publication elsewhere**. The circuits shown have NOT been proven by us. **Ingenuity Unlimited** is open to ALL abilities, but items for consideration in this column should be word-processed, with a brief circuit description (between 100 and 500 words maximum) and include a full circuit diagram showing all component values. **Please draw all circuit schematics as clearly as possible.** Email your circuit ideas to: **fay.kearn@wimborne.co.uk**.

Your ideas could earn you some cash and a prize!

PicoScope 2000 Series
pico Technology

WIN A PICOSCOPE 22205A 25MHz USB OSCILLOSCOPE WORTH £159

This PicoScope 2205A Series oscilloscope offers a small, light, modern alternative to bulky benchtop devices. It is perfect for engineers on the move and ideal for a wide range of applications including design, test, education, service monitoring, fault finding and repair. The PicoScope 2205A comes with many great features including: • 2 channels • 25MHz bandwidth • 200MS/s sampling rate • Arbitrary waveform generator • Advanced digital triggers • Persistence display modes • USB connected and powered • Free software upgrades.

Minimal-component logic probes

Introduction

This *Ingenuity Unlimited* is about designing a logic probe – an instrument that indicates different voltage levels as logic states. For example, if you were measuring TTL logic levels then such a probe would indicate 'LOW' for voltages between 0V and 0.8V and 'HIGH' for voltages between 2.4V and 5.0V (these are the defined limits for the logic levels). Similarly, for CMOS logic operating from a 3.0V supply, the limits for LOW would be 0V to 0.9V (30% of supply) and HIGH would be 2.1V (70% of supply) to 3.0V. It is also useful to indicate the 'forbidden zone' between the two correct limits of operation, as this can be handy when detecting problems such as floating inputs.

Although used in digital circuits, these instruments are designed using analogue circuitry, usually comparators, so that the voltage levels are accurately referenced. ('Accurately' here is a relative term; it is not suggested that precision measurements are required.) It is also standard practice to power such instruments directly from the logic supply of the circuit under test, so that the voltage levels reflect actul operating conditions.

LM393-based logic probe

This design uses a dual comparator with open-collector outputs, and has steering diodes to cause the indicator LEDs to light appropriately – see Fig.1. Both comparators are OFF for a logic LOW, thus only the green LED is illuminated. When the input level rises above the LOW limit the lower comparator turns ON, extinguishing the green LED and illuminating the amber LED. When the level rises to the HIGH limit, the upper comparator turns ON, illuminating the red LED and extinguishing the amber LED. The logic levels are set by the 15kΩ – 22kΩ – 15kΩ resistor chain; these values give a good approximation to the 30% and 70% limits of CMOS logic. (For TTL levels with a 5V supply, the corresponding resistor chain values are 27kΩ – 15kΩ – 8.2kΩ.)

The combined input bias current of the two comparator inputs is typically 50nA, thus the loading on the test point is effectively zero. The additional protection components are only required if voltages outside the supply are liable to be encountered, such as might occur in a mix of analogue and digital components; but with logic-only circuits they are unlikely to be needed. The circuit typically draws 0.4mA, plus the current for the LED(s).

The use of steering diodes makes for a simple and compact layout, but there are still six resistors and two diodes required in addition to the IC, plus the three LEDs.

To demonstrate this concept, the components were assembled on a small piece of stripboard, which was simply glued to a used marker pen. The result, shown in Fig.2 is effective and functional, but is untidy and clearly can be improved.

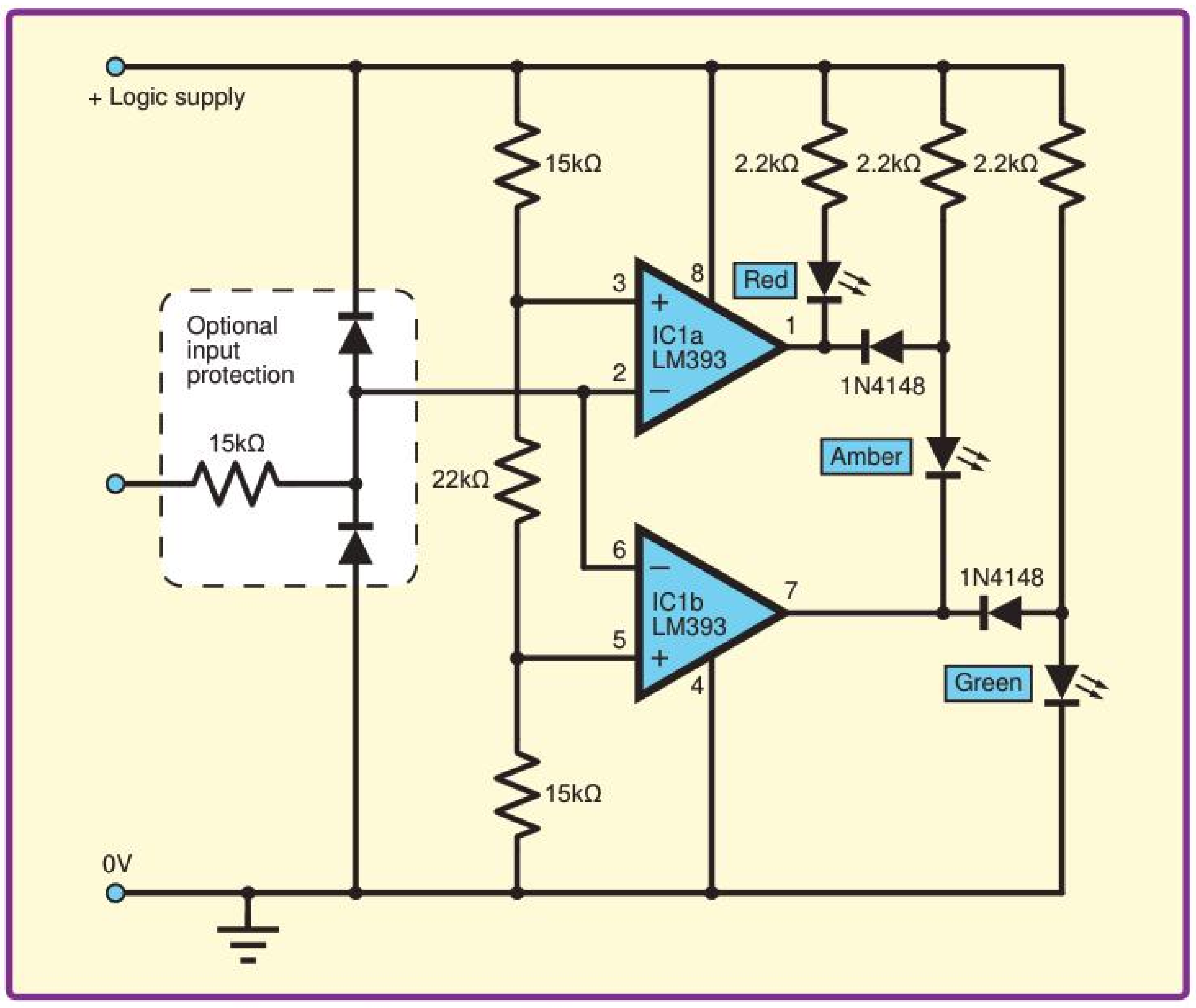


Fig.1. Fig.1. LM393-based logic probe

Parts list – LM393-based logic probe

IC1	LM393N
Diodes	2 off 1N4148
LEDs	1 off, 3mm of each: red, amber, green
Resistors	All 0.25w, 5%: 3 off 2.2kΩ, 2 off, 15kΩ, 1 off 22kΩ

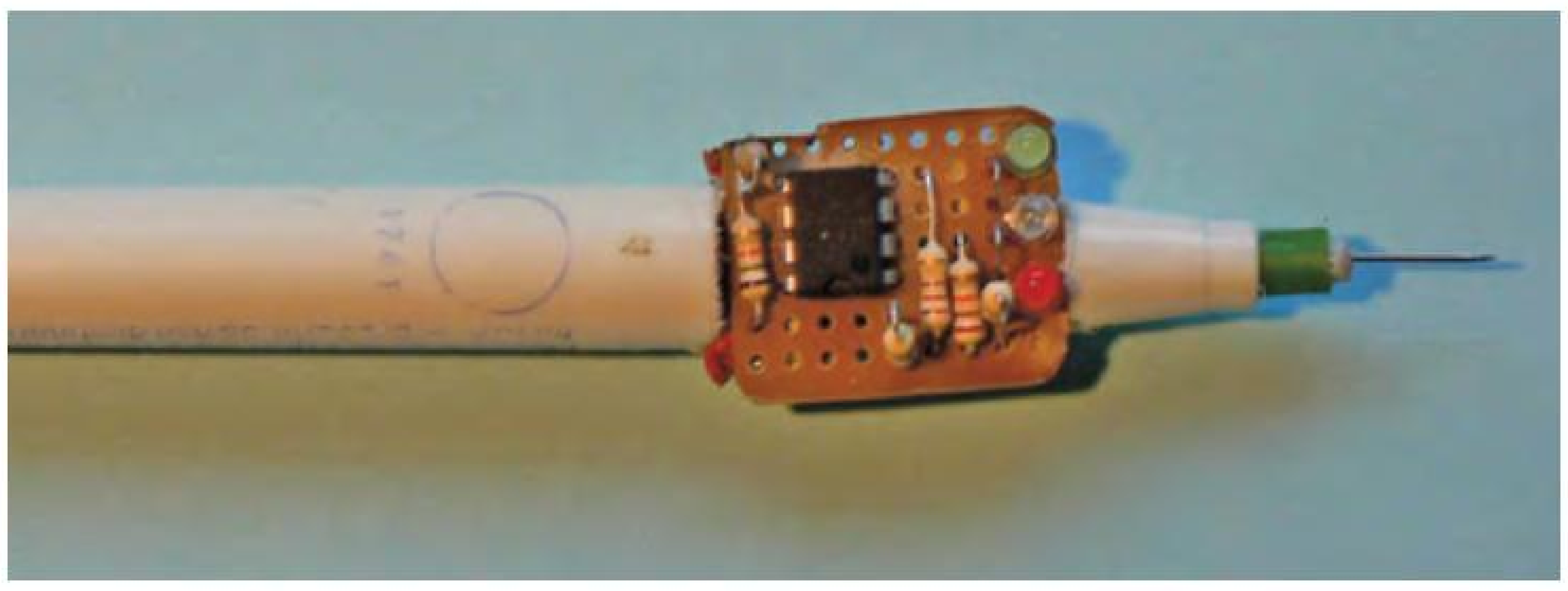


Fig.2. First construction of the LM393 probe

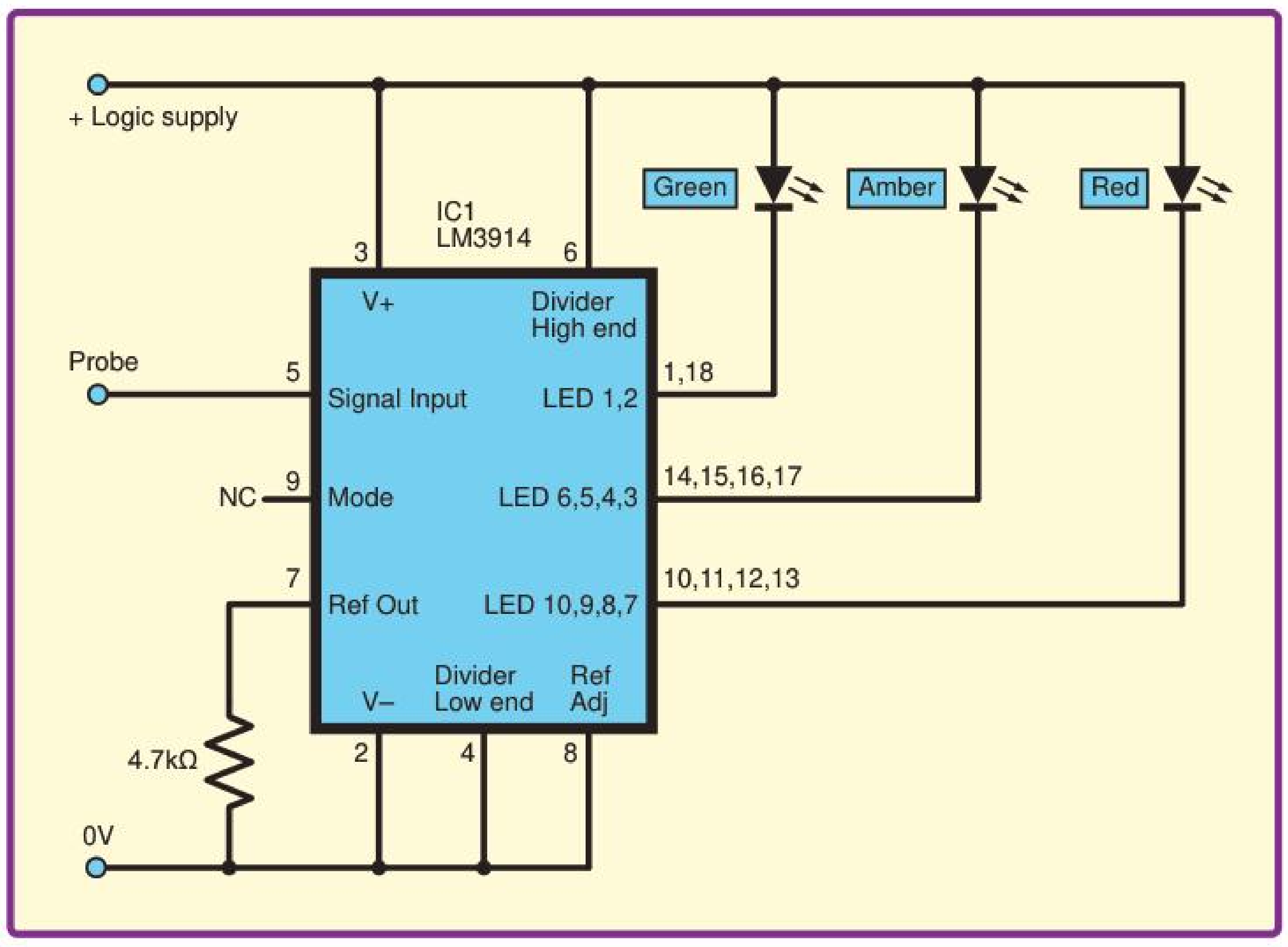

+ Logic supply
IC1
LM3914
3
6
Green
Amber
Red
V+
Divider
High end
Probe
5
Signal Input
LED 1,2
1,18
NC
9
Mode
LED 6,5,4,3
14,15,16,17
7
Ref Out
LED 10,9,8,7
10,11,12,13
Divider
Low end
Ref
Adj
V–
2
4
8
4.7kΩ
0V

Fig.3. LM3914-based logic probe

LM3914-based logic probe

I then decided to try and minimise the component count of the probe. The result uses only one resistor to complement IC1 (LM3914) and three LEDs – which one might think is the minimum possible component count. However, in this design the three LEDs are in fact a single tri-colour LED with a common anode, thus reducing the actual total component count to three items, as shown in Fig.3.

The LM3914 is a display IC designed by National-Semiconductor and made by Texas Instruments. It is typically used as an LED driver intended for moving dot/bar displays, such as volume indicators. It can operate with a supply voltage as low as 3V. The IC contains ten voltage comparators and a voltage divider. Each comparator drives a constant-current transistor output (see Fig.4). At a stroke, such a device eliminates both the voltage divider resistors and the current-limit resistors for the LEDs. The remaining single resistor is required to set the current level for all outputs.

The LM3914 has a typical input bias current of 25nA, with the additional advantage that the input can withstand voltages of ±35V without protection components. However, it is relatively current-hungry; the entire circuit draws around 10mA, with the illuminated LED taking only 2.5mA of this. (This is, of course, only a consideration in micropower circuits powered by a small battery.) The 3914 is designed to operate with an unsmoothed supply to the LEDs, and in practice appears to be stable with no supply decoupling.

If the voltage divider chain is connected across the logic supply voltage, each comparator will indicate voltage levels over one tenth of this range. Because of the constant-current nature of the outputs, these may be commoned, thus grouping the lower three, the middle four and the upper three outputs will in theory give the CMOS-level indications previously discussed. In practice, because the lowest comparator is biased at 10% of the divider chain voltage, there is no indication for the *lowest* 10% of the range, and the grouping of the outputs, as shown on the circuit diagram, reflects this. This then leaves the problem of how to show LOW logic levels below 10% of the supply (and the majority of logic produces such levels under normal conditions).

Overcoming the problem of no indication at the lowest input voltage could be easily solved using further logic, but that would defeat the whole point of this minimum-part-count design. So, is the LM393 circuit a better and cheaper circuit?

One approach to using the LM3914 is to offset the comparator voltage divider by a negative voltage, but this involves power supply complexities, which again defeats the purpose of the project. The pragmatic solution is to simply accept the situation – any other voltage will light an LED – which can be quickly verified by checking a known HIGH point. The absence of an illuminated LED is a guarantee of a good LOW level.

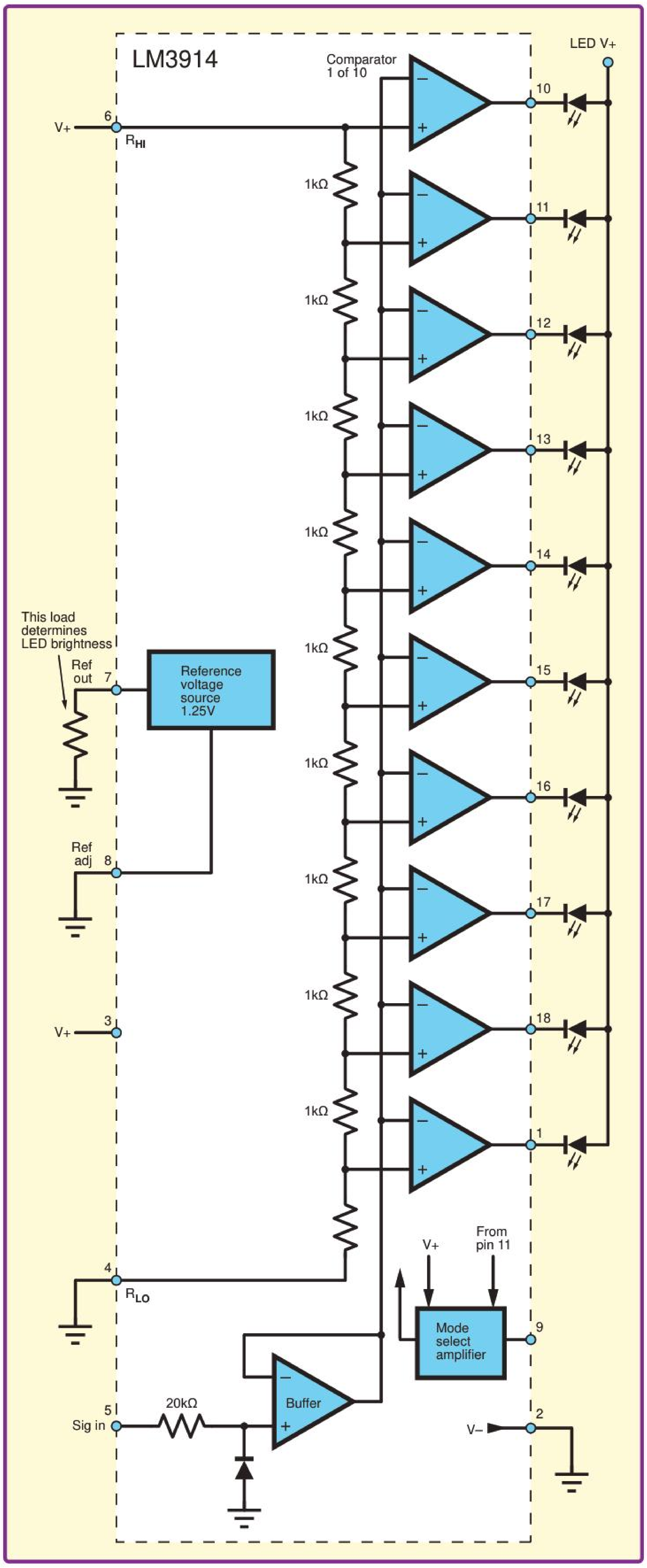

LM3914
Comparator
1 of 10
LED V+
V+
6
R_{HI}
1kΩ
1kΩ
1kΩ
1kΩ
1kΩ
1kΩ
1kΩ
1kΩ
1kΩ
10
11
12
13
14
15
16
17
18
1
This load
determines
LED brightness
Ref
out 7
Reference
voltage
source
1.25V
Ref
adj 8
V+
3
4
R_{LO}
V+
From
pin 11
Mode
select
amplifier
9
5
Sig in
20kΩ
Buffer
2
V–

Fig.4. Internal details of the LM3914 IC

Parts list – LM3914-based logic probe

IC	1 off LM3914N
LEDs	1 off, 3mm of each: red, amber, green
Resistors	All 0.25w, 5%: 1 off 4.7kΩ

Construction of a 3914-based probe

The probe is contained in the case of a coloured marker, which has a diameter of around 20mm. The branding of the particular marker shown was found to be soluble in methylated spirit, making it easy to produce a plain white background for the LEDs. A half-section of the marker case is cut out (a Dremel tool makes this a simple task) and the internal cartridge removed. This leaves plenty of space for the few components – see Fig.5.

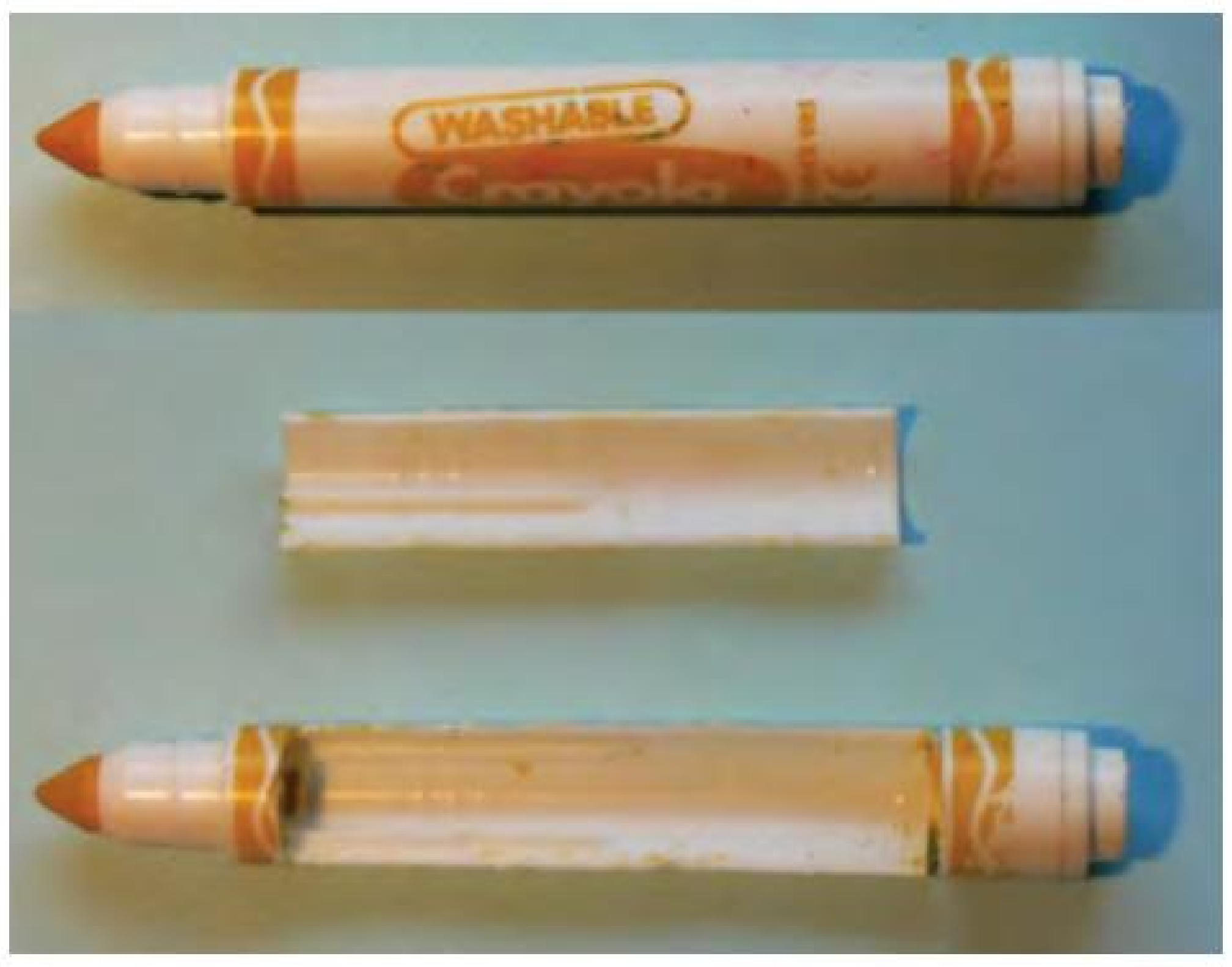


Fig.5. From magic marker to probe case

It is a matter of personal choice as to whether the LEDs and the IC are fitted into the body of the probe or into the 'lid'. I decided that the supply leads and probe needed to be well anchored, and this is easier when the other parts can be removed. It was also easier to use separate LEDs rather than the (larger) tri-colour LED previously discussed.

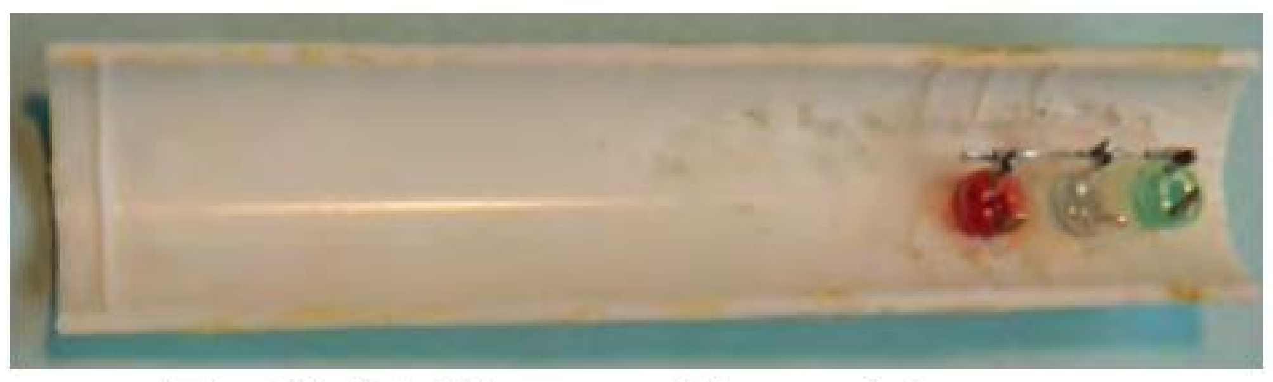


Fig.6. LEDs positioned in case

The LEDs are first fitted and glued into 2.8mm holes (for standard 3mm LEDs), as shown in Fig.6. Next, the IC is wired and secured. Gel superglue or latex (eg, Copydex) are effective adhesives for this purpose. With such a simple circuit a PCB is unnecessary; the IC leads are simply bent to make commoning easier and bare wire links fitted, as shown in Fig.7. This process is quick and easy, but a steady hand and a fine soldering iron are required.

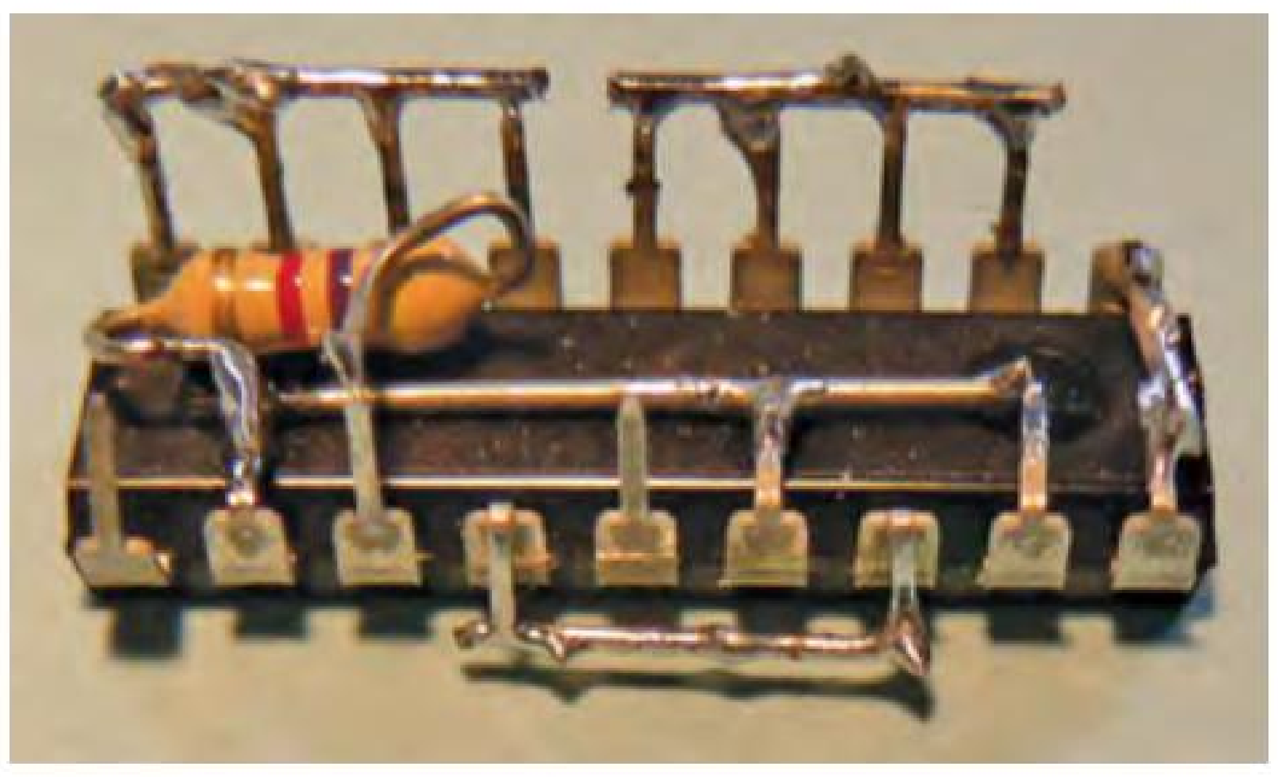


Fig.7. Commoning LM3914 'legs'

The power leads pass through a small hole drilled in the base of the marker, and are secured inside by a large knot. The connectors for these wires should suit the application; in this case, they were terminated in bare wires to plug directly into a solderless breadboard. The probe can be any suitable length of stiff wire. I do not recommend using a needle – such a fine point is unnecessary, and a potential hazard. Fine spring wire is ideal. If a scrap 3.5-inch diskette (a rarity today) can be found, the sliding cover contains a suitable spring (Fig.8). Straighten the spring and push it though the spongy tip of the marker. I found that the spring material solders readily. The completed probe is shown in Fig.9 and Fig.10.

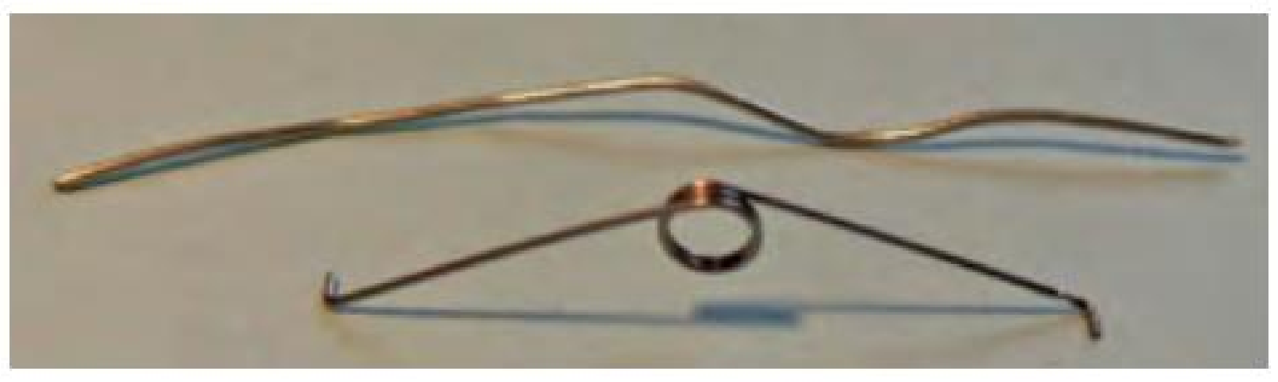


Fig.8. My probe tip was made from a spring

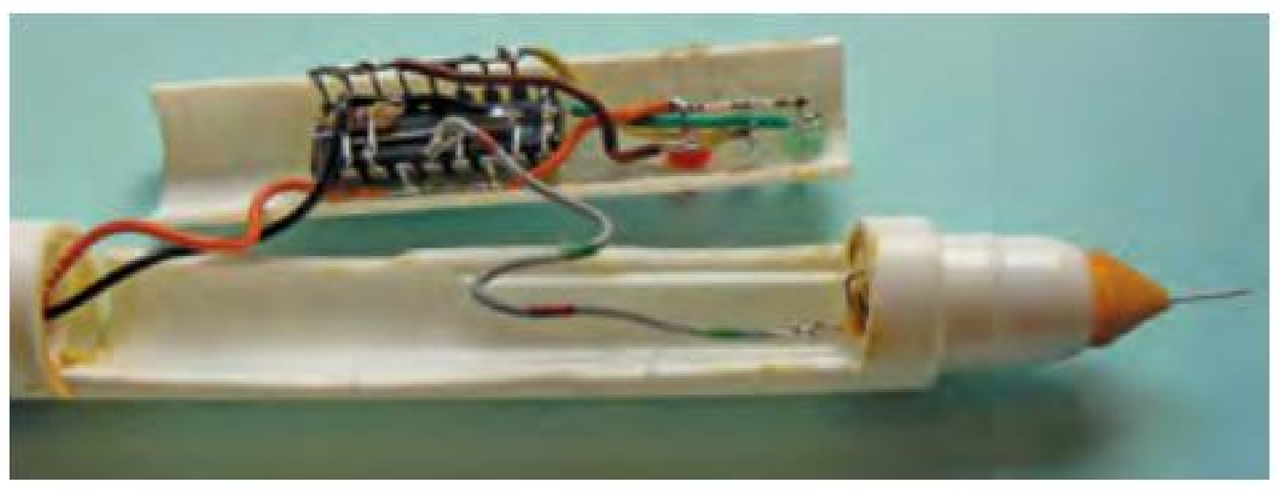


Fig.9. LM3914 inside the case

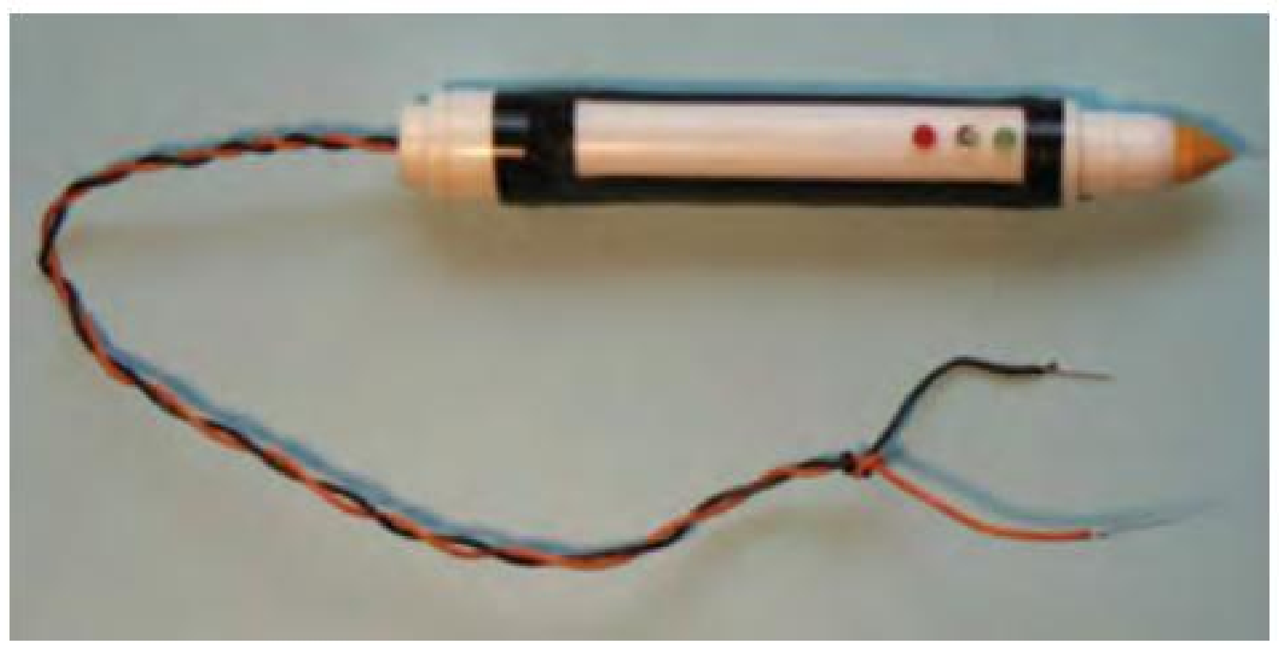


Fig.10. Ready to probe logic signals!

Conclusion

A bare minimum design has been presented and its drawbacks discussed. Clearly, sometimes the maxim that 'less is more' is not justified in practice, as both the performance and the cost of the minimal LM3914-based probe are inferior to the LM393-based design. The only minor drawback to the LM393 circuit is the need to have some form of circuit board for the multiple components. In practice, a small piece of pad board houses everything satisfactorily (Fig.11) and, as the resultant size is only some 14mm longer than the bare 3914 package, the same marker pen body can house everything without difficulty. The LEDs can be fitted on the (extended) board if this makes construction easier. (Note that a tri-colour LED *cannot* be used in the 393-based design.)

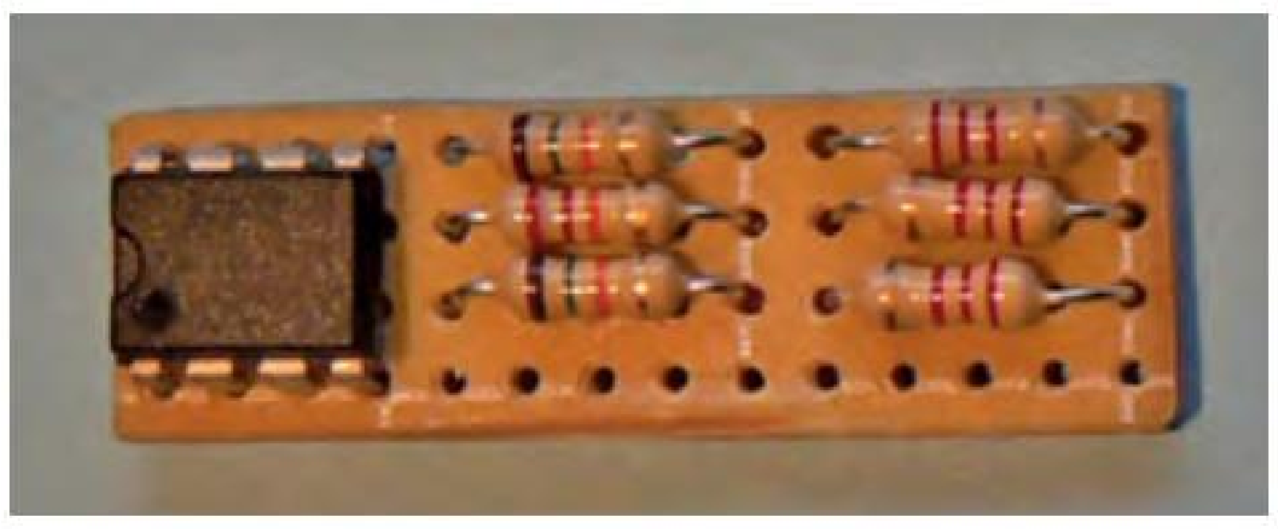


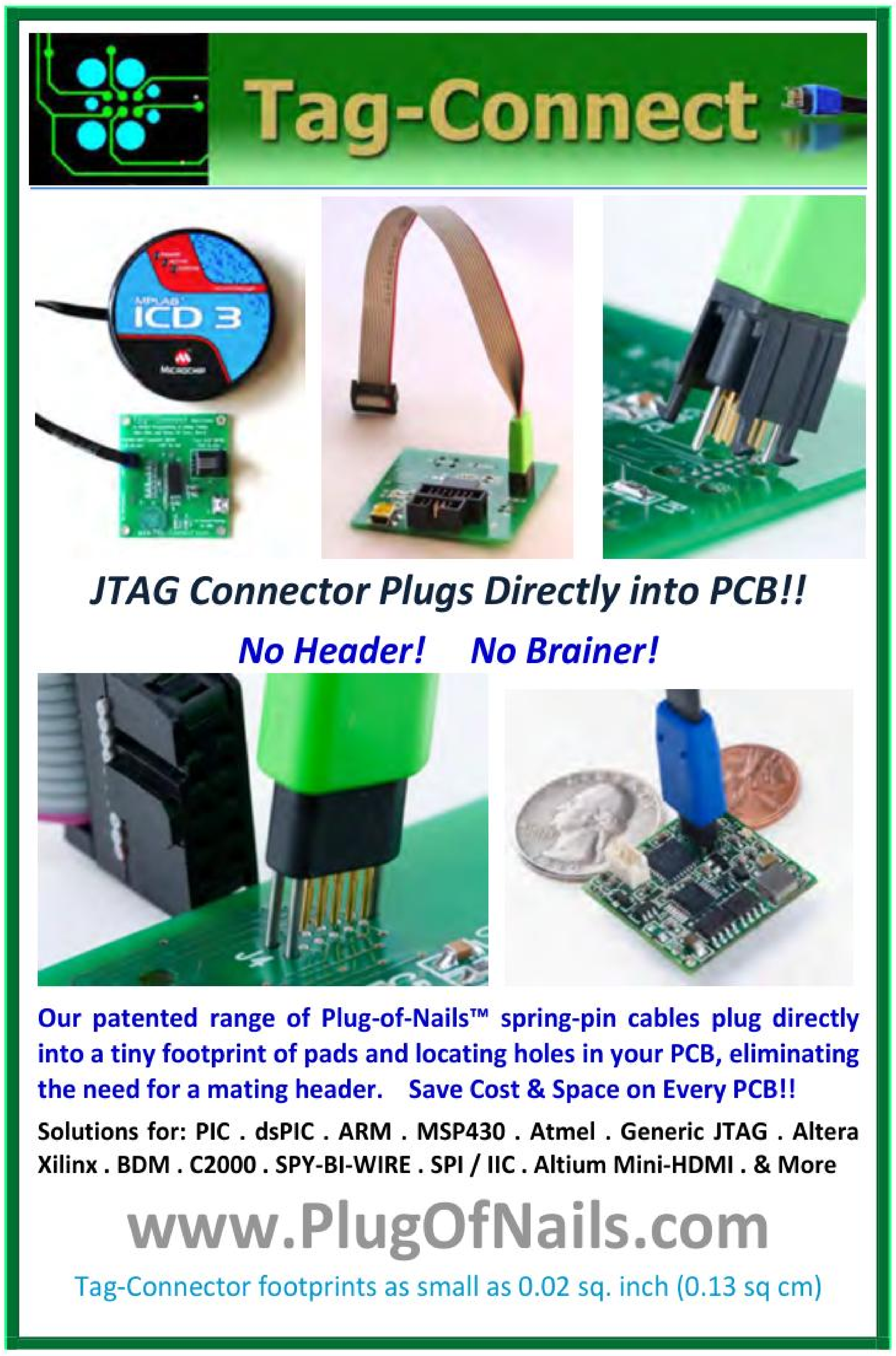
Fig.11. LM393 circuit on a small piece of board

Ross Henderson

WIN A PICOSCOPE 22205A 25MHz USB OSCILLOSCOPE WORTH £159

If you have a novel circuit idea which would be of use to other readers, then a Pico Technology 22205A 25MHz USB Oscilloscope could be yours.

After every 20 published IU circuits, the best entry will be awarded a Series oscilloscope worth £159.


Tag-Connect

JTAG Connector Plugs Directly into PCB!!

No Header! No Brainer!

Our patented range of Plug-of-Nails™ spring-pin cables plug directly into a tiny footprint of pads and locating holes in your PCB, eliminating the need for a mating header. Save Cost & Space on Every PCB!!

Solutions for: PIC . dsPIC . ARM . MSP430 . Atmel . Generic JTAG . Altera Xilinx . BDM . C2000 . SPY-BI-WIRE . SPI / IIC . Altium Mini-HDMI . & More

www.PlugOfNails.com

Tag-Connector footprints as small as 0.02 sq. inch (0.13 sq cm)

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

From £49.00

FEATURED IN OUR TEACH-IN 2015 SERIES

TINA Design Suite V10

Analogue, Digital, Symbolic, RF, MCU and Mixed-Mode Circuit Simulation and PCB Design with TINA

TINA Design Suite V10 is a powerful yet affordable software package for analysing, designing and real time testing analogue, digital, MCU, and mixed electronic circuits and their PCB layouts. You can also analyse RF, communication, optoelectronic circuits, test and debug microcontroller applications.

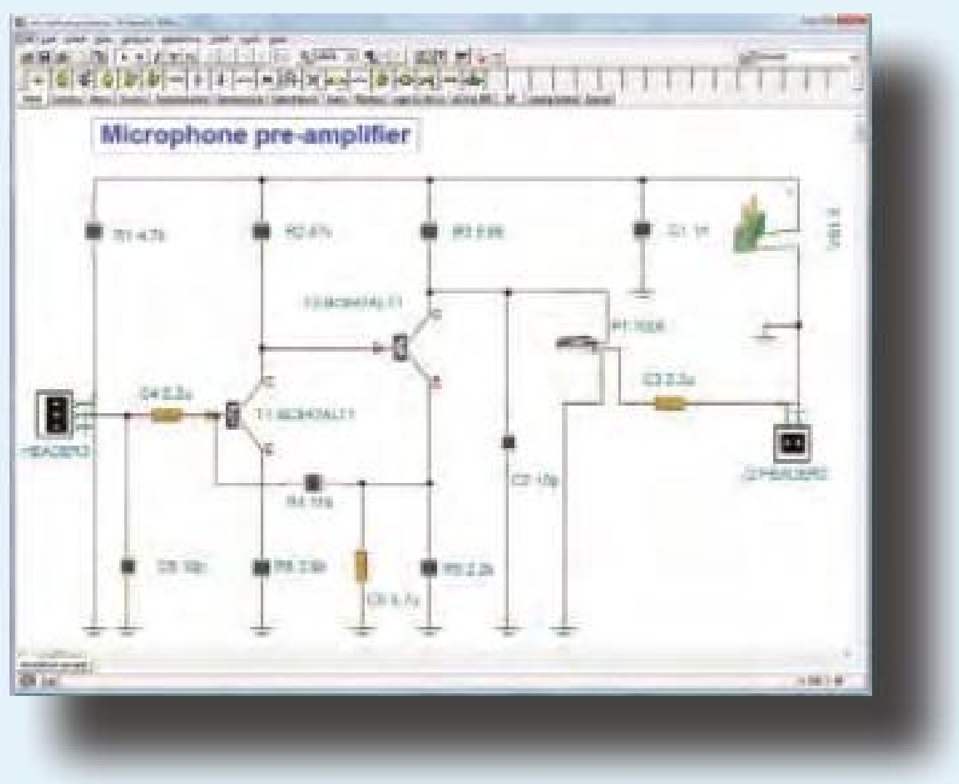
Enter and analyse any circuit up to 100 nodes (student), or 200 with the Basic (Hobbyist) version within minutes with TINA's easy-to-use schematic editor. Enhance your schematics by adding text and graphics. Choose components from the large library containing more than 10,000 manufacturer models. Analyse your circuit through more than 20 different analysis modes or with 10 high tech virtual instruments.

Present your results in TINA's sophisticated diagram windows, on virtual instruments, or in the live interactive mode where you can even edit your circuit during operation.

Customise presentations using TINA's advanced drawing tools to control text, fonts, axes, line width, colour and layout. You can create and print documents directly inside TINA or cut and paste your results into your favourite word procesing or DTP package.

TINA includes the following Virtual Instruments: Oscilloscope, Function Generator, Multimeter, Signal Analyser/Bode Plotter, Network Analyser, Spectrum Analyser, Logic Analyser, Digital Signal Generator, XY Recorder.

This offer gives you a CD-ROM – the software will need registering (FREE) with Designsoft (TINA), details are given within the package.



Get TINA Basic V11 (Hobbyist) for £129 or Student V10 version for £49

Prices include VAT and UK postage

+ get a 1 year free subscription for TINACloud the breakthrough cloud version of TINA which you can run on most operating systems and computers, including PCs, Macs, thin clients iPads and other tablets – even on many smart phones, smart TVs and e-book readers.

To order please either fill out and return the order form, or call us on 01202 880299

Alternatively you can order via our secure online shop at: www.epemag.com

ELECTRONICS TEACH-IN 2

ELECTRONICS TEACH-IN 2 CD-ROM
USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers. An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

CD-ROM **Order code ETI2 CD-ROM** **£9.50**

ELECTRONICS TEACH-IN 3

ELECTRONICS TEACH-IN 3 CD-ROM

The three sections of this CD-ROM cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on circuit design problems – from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered. Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 circuit designs submitted by the readers of *EPE*.

The CD-ROM also contains the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial).

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC.

CD-ROM **Order code ETI3 CD-ROM** **£8.50**

ELECTRONICS TEACH-IN 4

ELECTRONICS TEACH-IN 4 CD-ROM

A Broad-Based Introduction to Electronics.

The Teach-In 4 CD-ROM covers three of the most important electronics units that are currently studied in many schools and colleges. These include, Edexcel BTEC level 2 awards and the electronics units of the new Diploma in Engineering, Level 2.

The CD-ROM also contains the full Modern Electronics Manual, worth £29.95. The Manual contains over 800 pages of electronics theory, projects, data, assembly instructions and web links.

A package of exceptional value that will appeal to all those interested in learning about electronics or brushing up on their theory, be they hobbyists, students or professionals.

CD-ROM **Order code ETI4 CD-ROM** **£8.99**

ELECTRONICS TEACH-IN 4
A BROAD-BASED INTRODUCTION TO ELECTRONICS
THE MODERN ELECTRONICS MANUAL
BASE MANUAL
ELECTRONICS TEACH-IN 3
CIRCUIT SURGERY
PRACTICALLY SPEAKING
INGENUITY UNLIMITED

NEW ELECTRONICS TEACH-IN BUNDLE – SPECIAL BUNDLE PRICE £14 FOR PARTS 1, 2, 3 & 4

CD-ROMs **Order code ETIB2** Bundle Price **£18.95**

PICmicro TUTORIALS AND PROGRAMMING

HARDWARE

PICmicro Multiprogrammer Board and Development Board

Suitable for use with the three software packages listed below

This flexible PICmicro microcontroller programmer board and combination board allows students and professional engineers to learn how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40 pin devices from the 12, 16 and 18 series PICmicro ranges. For those who want to learn, choose one or all of the packages below to use with the hardware.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual LEDs, quad 7-segment display and alphanumeric LCD display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Compatible with the E-blocks range of accessories

£118 including VAT and postage

SOFTWARE

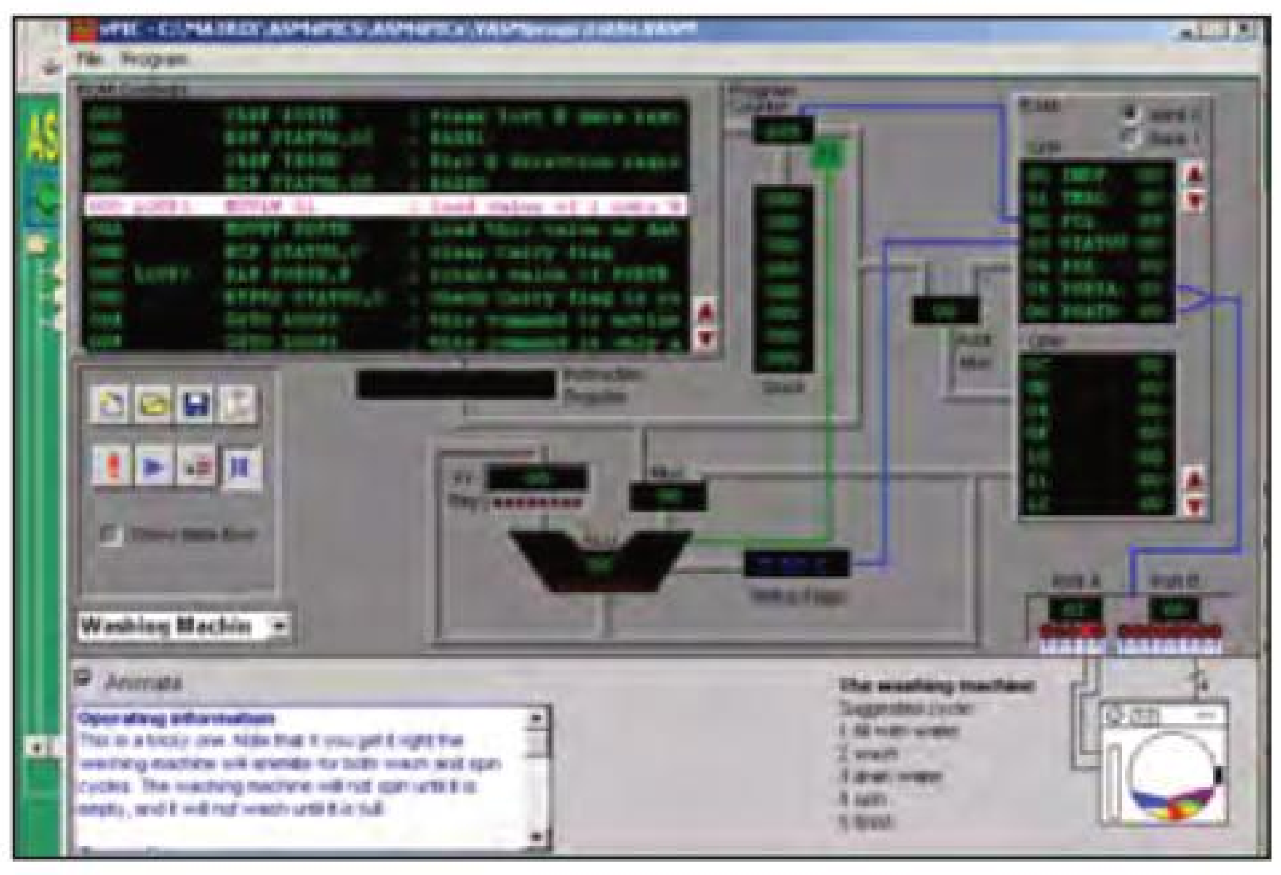
ASSEMBLY FOR PICmicro V6

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84, 16F88 and 16F877a PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

• Comprehensive instruction through 45 tutorial sections • Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator • Tests, exercises and projects covering a wide range of PICmicro MCU applications • Includes MPLAB assembler • Visual representation of a PICmicro showing architecture and functions • Expert system for code entry helps first time users • Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) • Imports MPASM files.

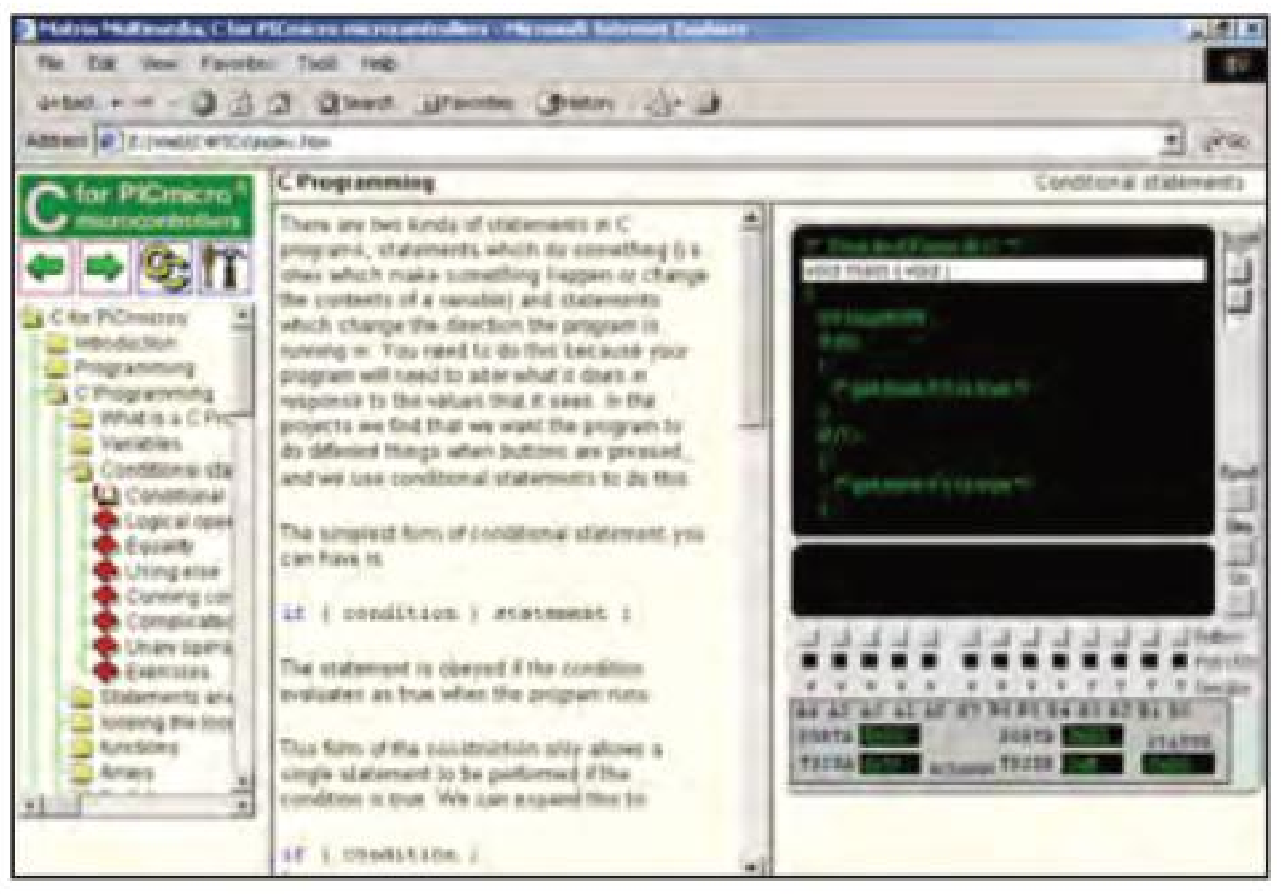


'C' FOR 16 Series PICmicro Version 5

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

• Complete course in C as well as C programming for PICmicro microcontrollers • Highly interactive course • Virtual C PICmicro improves understanding • Includes a C compiler for a wide range of PICmicro devices • Includes full Integrated Development Environment • Includes MPLAB software • Compatible with most PICmicro programmers • Includes a compiler for all the PICmicro devices.



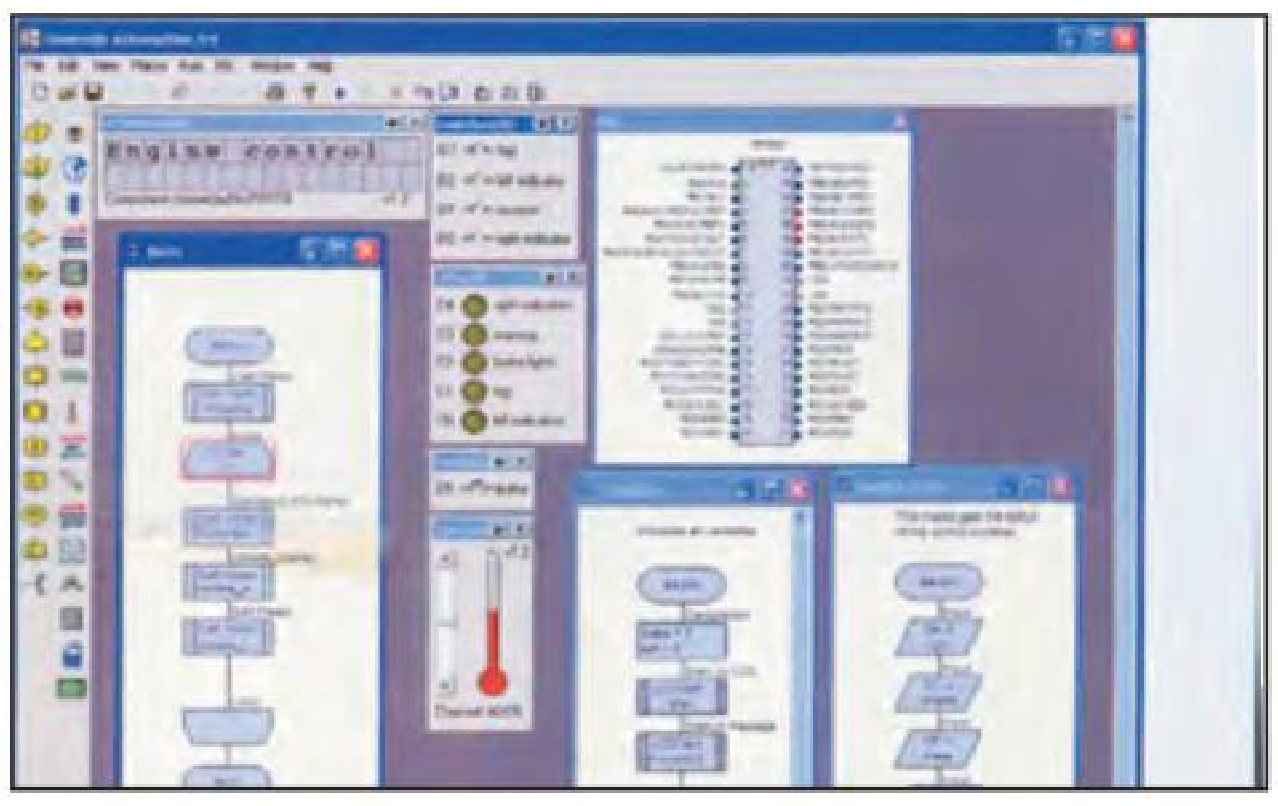
This software will run on Windows XP or later operating systems

FLOWCODE FOR PICmicro V7

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces code for a wide range of devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

Please note: Due to popular demand, Flowcode is now available as a download. Please include your email address and a username (of your choice) on your order. A unique download code will then be emailed to you.



PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

(UK and EU customers add VAT to 'plus VAT' prices)

Single License . . . . £99 plus VAT

Site Licence . . . . £499 plus VAT

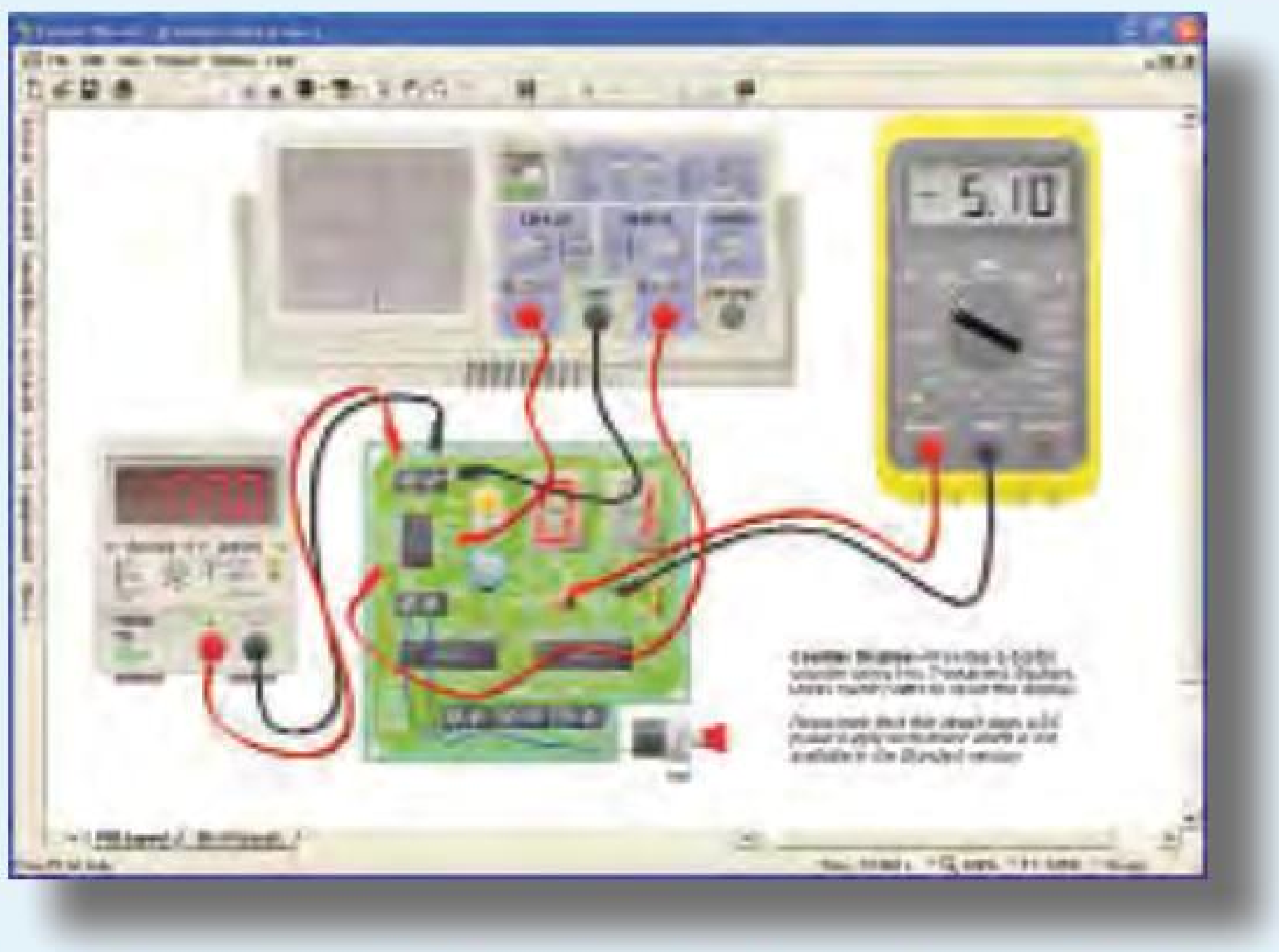
Flowcode . . . . Contact us for pricing
(choose PIC-8b, PIC-16b, PIC-32b, AVR/Arduino,ARM)

CIRCUIT WIZARD

Circuit Wizard is a revolutionary software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package.
Two versions are available, Standard or Professional.

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

** Circuit diagram design with component library (500 components Standard, 1500 components Professional) * Virtual instruments (4 Standard, 7 professional) * On-screen animation * Interactive circuit diagram simulation * True analogue/digital simulation * Simulation of component destruction * PCB Layout * Interactive PCB layout simulation * Automatic PCB routing * Gerber export * Multi-level zoom (25% to 1000%) * Multiple undo and redo * Copy and paste to other software * Multiple document support*



This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

Standard **£61.25** inc. VAT. Professional **£75** plus VAT.

GCSE ELECTRONICS

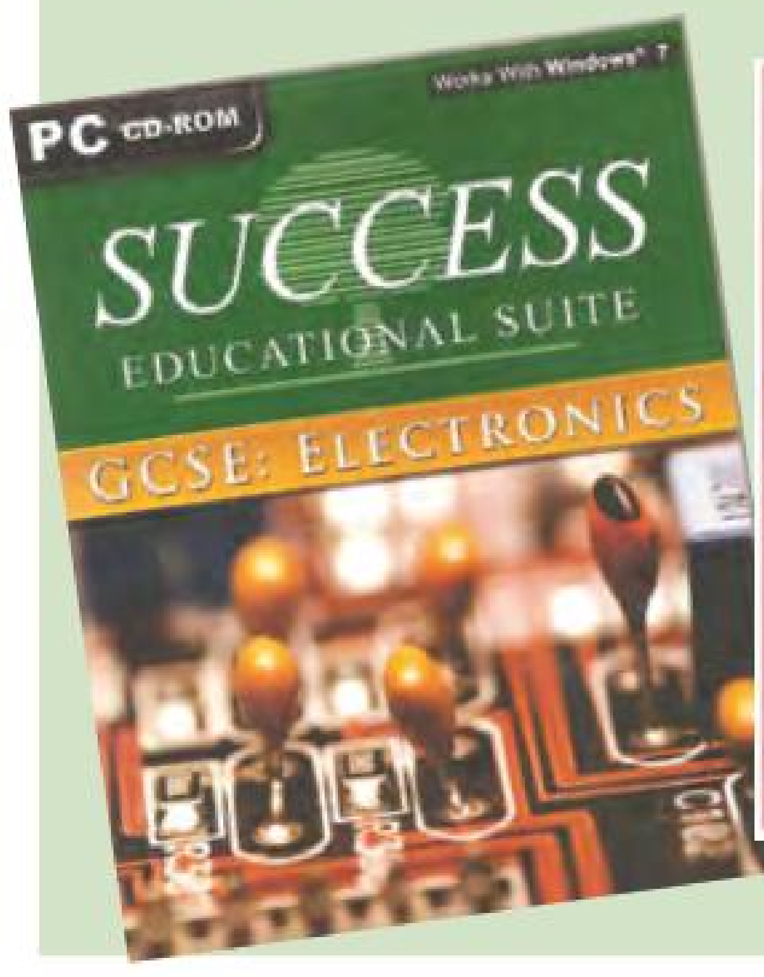
Suitable for any student who is serious about studying and who wants to achieve the best grade possible. Each program's clear, patient and structured delivery will aid understanding of electronics and assist in developing a confident approach to answering GCSE questions. The CD-ROM will be invaluable to anyone studying electronics, not just GCSE students.

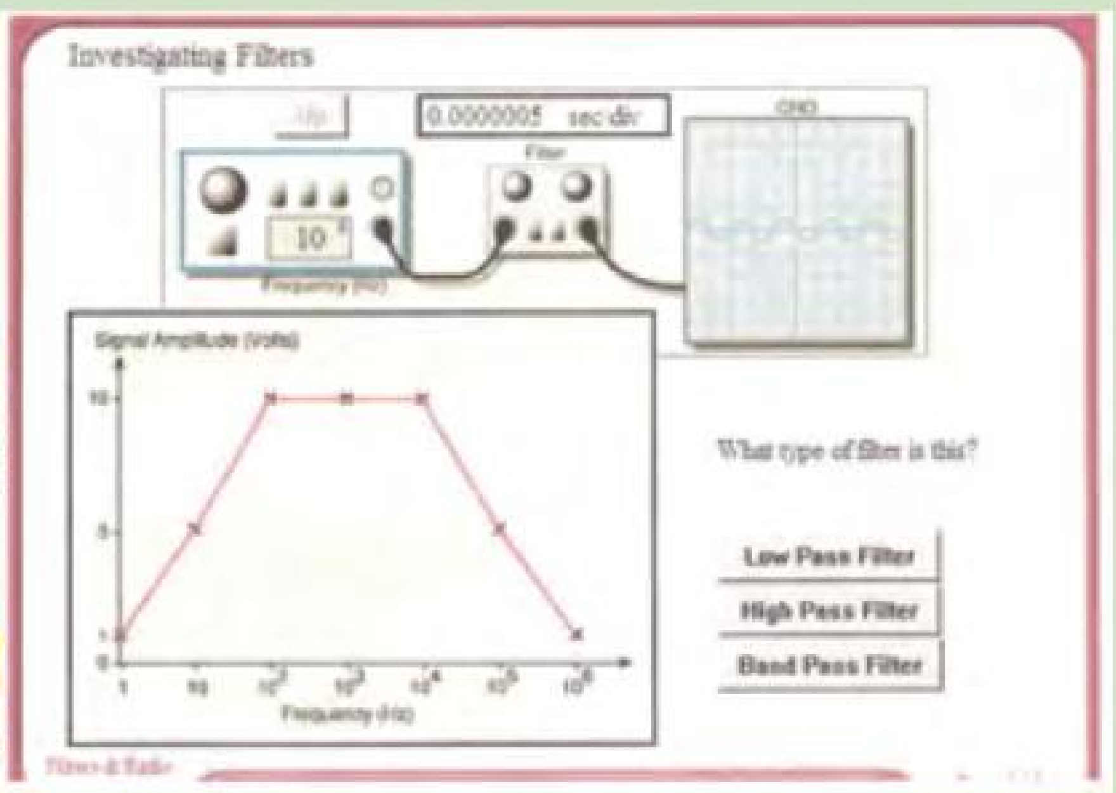
**** Contains comprehensive teaching material to cover the National Curriculum syllabus * Regular exercises reinforce the teaching points * Retains student interest with high quality animation and graphics * Stimulates learning through interactive exercises * Provides sample examination ques-tions with model solutions * Authored by practising teachers * Covers all UK examination board syllabuses * Caters for all levels of ability * Useful for self-tuition and revision***

SUBJECTS COVERED

Electric Circuits – Logic Gates – Capacitors & Inductors – Relays – Transistors – Electric Transducers – Operational Amplifiers – Radio Circuits – Test Instruments

Over 100 different sections under the above headings





£12.50 inc. VAT and P&P

Please send me: CD-ROM ORDER FORM

☐ **Assembly for PICmicro V5**
☐ **'C' for 16 Series PICmicro V5**

Version required:
☐ **Single License**
☐ **Site licence**

Note: The software on each version is the same, only the licence for use varies.

☐ **PICmicro Multiprogrammer Board and Development Board (hardware)**

☐ **Circuit Wizard – Standard**
☐ **Circuit Wizard – Professional**
☐ **GCSE Electronics**

☐ **TINA Design Suite V11 Basic (Hobbyist)**
☐ **TINA Design Suite V10 (Student)**

☐ **Teach-In 2**
☐ **Teach-In 3**
☐ **Teach-In 4**
☐ **Teach-In Bundle**

Full name: . . . .

Address: . . . .

. . . . Post code: . . . . Tel. No: . . . .

Signature: . . . .

☐ I enclose cheque/PO in £ sterling payable to WIMBORNE PUBLISHING LTD for £ . . . .
☐ Please charge my Visa/Mastercard: £ . . . .

Valid From: . . . . Card expiry date: . . . .

Card No: . . . .

Card Security Code . . . .
(The last 3 digits on or just under the signature strip)

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

ORDERING
ALL PRICES INCLUDE UK POSTAGE

Standard/Student/Basic (Hobbyist) Version price includes postage to most countries in the world
EU residents outside the UK add £5 for airmail postage per order

Single License and Site License Versions – overseas readers add £5 to the basic price of each order for airmail postage (**do not add VAT** unless you live in an EU (European Union) country, then add VAT at 20% or provide your official VAT registration number).

Send your order to:
Direct Book Service
Wimborne Publishing Ltd
113 Lynwood Drive, Merley,
Wimborne, Dorset BH21 1UU

To order by phone ring

01202 880299. Fax: 01202 843233
Goods are normally sent within seven days

E-mail: orders@wimborne.co.uk
Online shop:

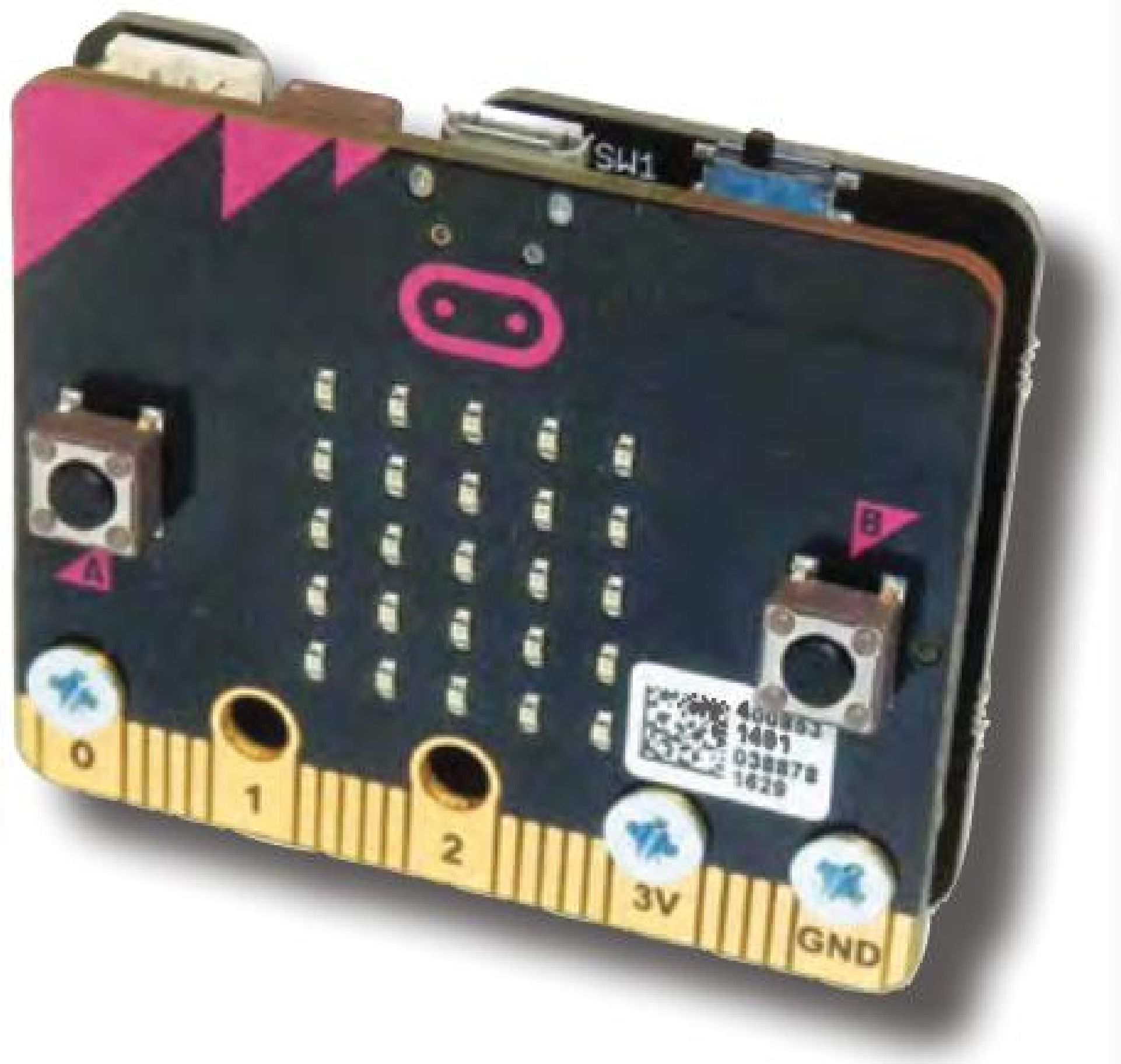
www.epemag.com

DIRECT BOOK SERVICE

Teach-In 2017

Introducing the BBC micro:bit

Part 1: Meet the micro:bit



The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last page.

FOR A FULL DESCRIPTION OF THESE BOOKS AND CD-ROMS SEE THE SHOP ON OUR WEBSITE www.epemag.com

All prices include UK postage

GETTING STARTED WITH THE BBC MICRO:BIT
Mike Tooley

IN FULL COLOUR
For Beginners of Any Age
Getting Started with the BBC micro:bit
Mike Tooley

Not just an educational resource for teaching youngsters coding, the BBC micro:bit is a tiny low cost, low-profile ARM-based single-board computer. The board measures 43mm × 52mm but despite its diminutive footprint it has all the features of s fully fledged microcontroller together with s simple LED matrix display, two buttons, an accelerometer and a magnetometer.

Mike Tooley's book will show you how the micro:bit can be used in a wide range of applications from simple domestic gadgets to more complex control systems such as those used for lighting, central heating and security applications. Using Microsoft Code Blocks, the book provides a progressive introduction to coding as well as interfacing with sensors and transducers.

Each chapter concludes with a simple practical project that puts into practice what the reader has learned. The featured projects include an electronic direction finder, frost alarm, resction tester, battery checker, thermostatic controller and a passive infrared (PIR) security alarm.

No previous coding experience is assumed, making this book ideal for complete beginners as well as those with some previous knowledge. Self-test questions are provided at the end of each chapter together with answers at the end of the book. So whatever your starting point, this book will take you further along the road to developing and coding your own real-world applications.

108 Pages Order code BBC MBIT £7.99

THEORY AND REFERENCE

PRACTICAL ELECTRONICS HANDBOOK – 6th Edition. Ian Sinclair
440 pages Order code NE21 £33.99

Starting Electronics

STARTING ELECTRONICS – 4th Edition
Keith Brindley
296 pages Order code NE100 £18.99

ELECTRONIC CIRCUITS – FUNDAMENTALS & APPLICATIONS – Third Edition Mike Tooley
400 pages Order code TF43 £25.99

FUNDAMENTAL ELECTRICAL AND ELECTRONIC PRINCIPLES – Third Edition C.R. Robertson
368 pages Order code TF47 £21.99

A BEGINNER'S GUIDE TO TTL DIGITAL ICs
R.A. Penfold
142 pages OUT OF PRINT BP332 £5.45

UNDERSTANDING ELECTRONIC CONTROL SYSTEMS
Owen Bishop
228 pages Order code NE35 £36.99

PROJECT CONSTRUCTION

IC 555 PROJECTS
E. A. Parr
167 pages Order code BP44 £5.49

ELECTRONIC PROJECT BUILDING FOR BEGINNERS R. A. Penfold
135 pages Order code BP392 £5.99

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
132 pages Order code BP374 £5.45

MICROPROCESSORS

INTERFACING PIC MICROCONTROLLERS – SECOND EDITION Martin Bates
298 pages Order code NE48 £34.99

PROGRAMMING 16-BIT PIC MICROCONTROLLERS IN C – LEARNING TO FLY THE PIC24 Lucio Di Jasio (Application Segments Manager, Microchip, USA)
496 pages +CD-ROM Order code NE45 £38.00

INTRODUCTION TO MICROPROCESSORS AND MICROCONTROLLERS – SECOND EDITION John Crisp
222 pages Order code NE31 £29.99

THE PIC MICROCONTROLLER YOUR PERSONAL INTRODUCTORY COURSE – THIRD EDITION. John Morton
270 pages Order code NE36 £25.00

PIC IN PRACTICE (2nd Edition)
David W. Smith
308 pages Order code NE39 £24.99

MICROCONTROLLER COOKBOOK
Mike James
240 pages Order code NE26 £36.99

BOOK ORDERING DETAILS

All prices include UK postage. For postage to Europe (air) and the rest of the world (surface) please add £3 per book. Surface mail can take up to 10 weeks to some countries. For the rest of the world airmail add £4 per book. CD-ROM prices include VAT and/or postage to anywhere in the world. Send a PO, cheque, international money order (£ sterling only) made payable to **Direct Book Service** or card details, Visa, Mastercard or Maestro to: **DIRECT BOOK SERVICE, WIMBORNE PUBLISHING LIMITED, 113 LYNWOOD DRIVE, MERLEY, WIMBORNE, DORSET BH21 1UU**.

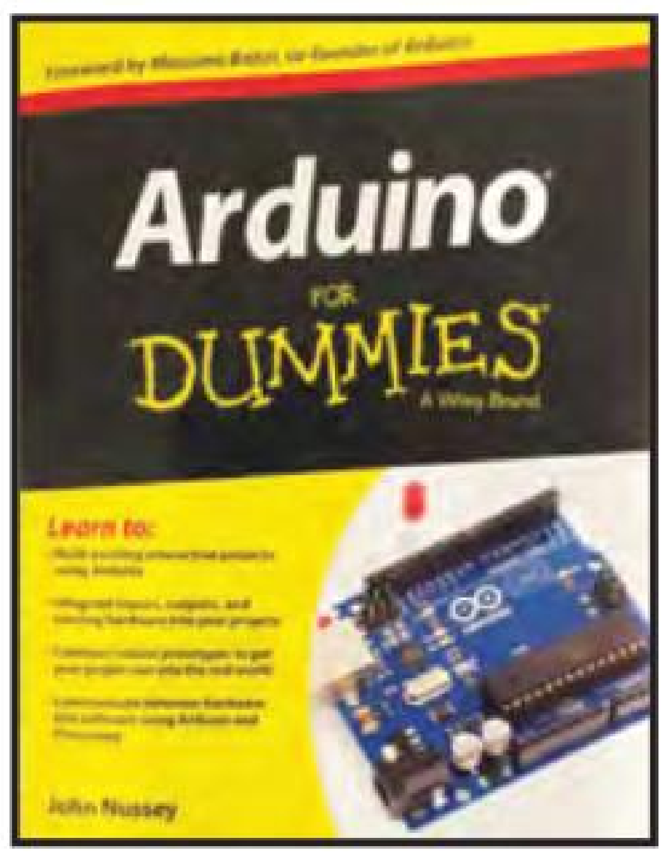
Books are normally sent within seven days of receipt of order, but please allow 28 days for delivery – more for overseas orders. *Please check price and availability (see latest issue of* Everyday Practical Electronics*) before ordering from old lists.*

For a full description of these books please see the shop on our website.
Tel 01202 880299 Fax 01202 843233. E-mail: dbs@wimborne.co.uk

Order from our online shop at: www.epemag.com

Teach-In 2016

Exploring the Arduino



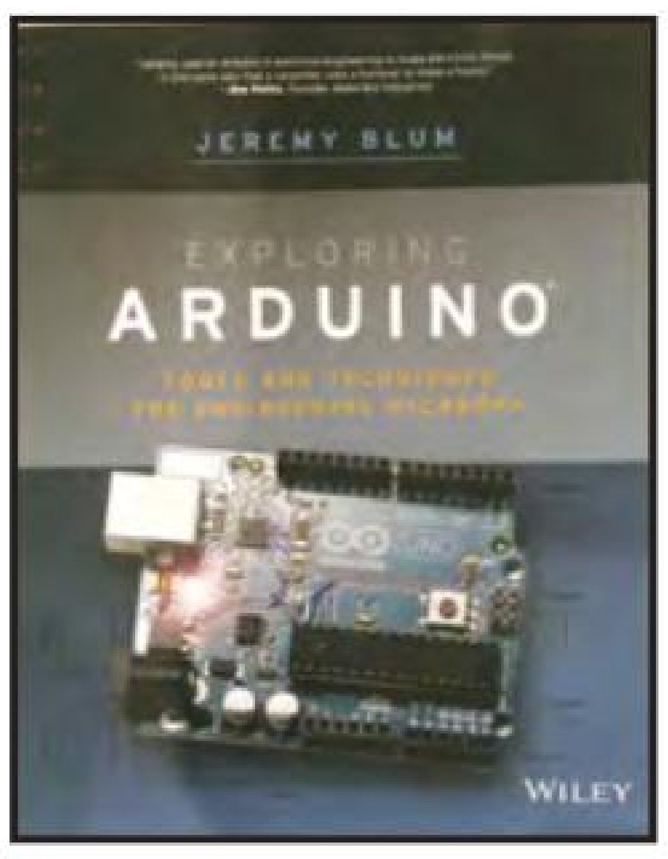
ARDUINO FOR DUMMIES

John Nussey

Arduino is no ordinary circuit board. Whether you're an artist, a designer, a programmer, or a hobbyist, Arduino lets you learn about and play with electronics. You'll discover how to build a variety of circuits that can sense or control real-world objects, prototype your own product, and even create interactive artwork. This handy guide is exactly what you need to build your own Arduino project – what you make is up to you!

- Learn by doing – start building circuits and programming your Arduino with a few easy examples – right away!
- Easy does it – work through Arduino sketches line by line, and learn how they work and how to write your own.
- Solder on! – don't know a soldering iron from a curling iron? No problem! You'll learn the basics and be prototyping in no time.
- Kitted out – discover new and interesting hardware to turn your Arduino into anything from a mobile phone to a Geiger counter.
- Become an Arduino savant – find out about functions, arrays, libraries, shields and other tools that let you take your Arduino project to the next level
- Get social – teach your Arduino to communicate with software running on a computer to link the physical world with the virtual world

438 Pages Order code ARDDUM01 £19.99



EXPLORING ARDUINO

Jeremy Blum

Arduino can take you anywhere. This book is the roadmap.

Exploring Arduino shows how to use the world's most popular microcontroller to create cool, practical, artistic and educational projects. Through lessons in electrical engineering, programming and human-computer interaction this book walks you through specific, increasingly complex projects, all the while providing best practices that you can apply to your own projects once you've mastered these. You'll acquire valuable skills – and have a whole lot of fun.

• Explore the features of several commonly used Arduino boards • Use the Arduino to control very simple tasks or complex electronics • Learn principles of system design, programming and electrical engineering • Discover code snippet, best practices and system schematics you can apply to your original projects • Master skills you can use for engineering endeavours in other fields and with different platforms

357 Pages Order code EXPARD01 £26.99

COMPUTING AND ROBOTICS

NEWNES INTERFACING COMPANION
Tony Fischer-Cripps
295 pages Order code NE38 £41.00

HOW TO BUILD A COMPUTER MADE EASY
R.A. Penfold
120 pages Order code BP707 £8.49

EASY PC CASE MODDING
R.A. Penfold
192 pages + CDROM Order code BP542 £8.99

FREE DOWNLOADS TO PEP-UP AND PROTECT YOUR PC
R.A. Penfold
128 pages Order code BP722 £7.99

WINDOWS XP EXPLAINED
N. Kantaris and P.R.M. Oliver
264 pages Order code BP514 £7.99

THE INTERNET – TWEAKS, TIPS AND TRICKS
R. A. Penfold
128 pages Order code BP721 £7.99

eBAY – TWEAKS, TIPS AND TRICKS
R. A. Penfold
128 pages Order code BP716 £7.50

AN INTRODUCTION TO eBAY FOR THE OLDER GENERATION
Cherry Nixon
120 pages Order code BP709 £8.49

HOW TO FIX YOUR PC PROBLEMS
R.A. Penfold
128 pages Order code BP705 £8.49

AN INTRODUCTION TO WINDOWS VISTA
P.R.M. Oliver and N. Kantarris
120 pages Order code BP703 £8.49

WINDOWS 8.1 EXPLAINED
180 Pages Order code BP747 £10.99

COMPUTING FOR THE OLDER GENERATION
Jim Gatenby
308 pages Order code BP601 £8.99

ANDROIDS, ROBOTS AND ANIMATRONS
Second Edition – John Iovine
224 pages Order code MGH1 £16.99

ROBOT BUILDERS COOKBOOK
Owen Bishop
366 pages Order code NE46 £26.00

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold
288 pages + Order code BP901 £14.99

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold
298 pages Order code BP902 £14.99

HOW TO FIX YOUR PC PROBLEMS
R. A. Penfold
128 pages Order code BP705 £8.49

WINDOWS 7 – TWEAKS, TIPS AND TRICKS
Andrew Edney
120 pages Order code BP708 £8.49

GETTING STARTED IN COMPUTING FOR THE OLDER GENERATION
Jim Gatenby
120 pages Order code BP704 £8.49

WINDOWS 8.1 EXPLAINED
Noel Kantaris
180 Pages Order code BP747 £10.99

COMPUTING WITH A LAPTOP FOR THE OLDER GENERATION
R.A. Penfold
120 pages Order code BP702 £8.49

AN INTRODUCTION TO EXCEL SPREADSHEETS
Jim Gatenby
18 pages Order code BP701 £8.49

AN INTRODUCTION TO THE NEXUS 7
118 Pages Order code BP744 £8.99

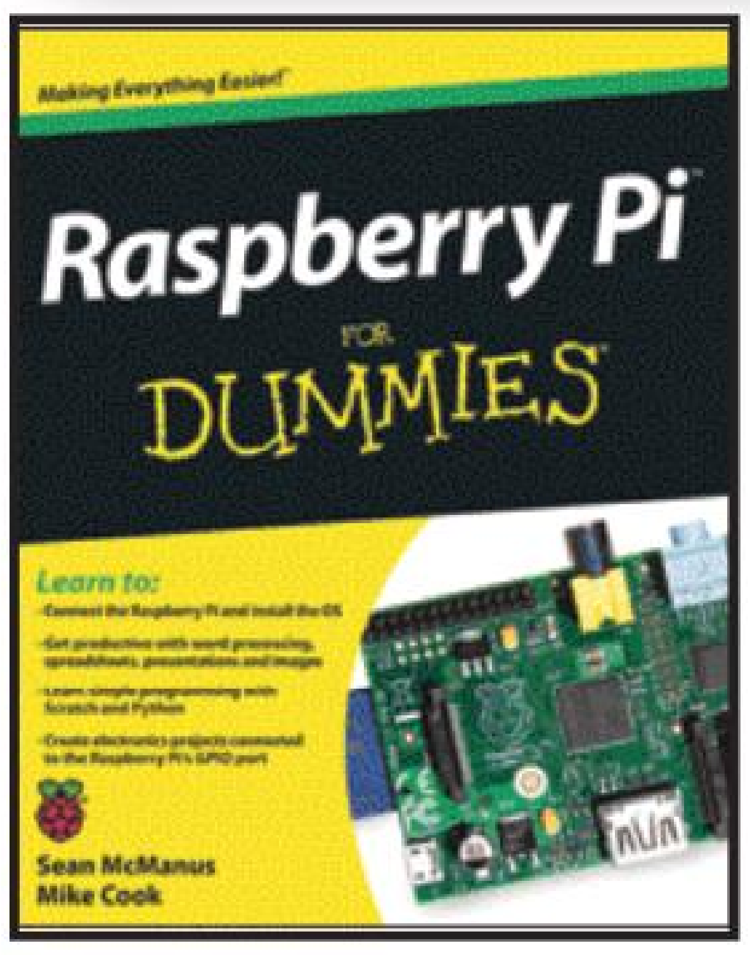
KINDLE FIRE HDX EXPLAINED
118 Pages Order code BP743 £8.99

AUDIO & VIDEO

VALVE AMPLIFIERS – Second Edition
Morgan Jones
288 pages Order code NE33 £40.99

BUILDING VALVE AMPLIFIERS
Morgan Jones
368 pages Order code NE40 £29.00

RASPBERRY PI



RASPBERRY Pi FOR DUMMIES

Sean McManus and Mike Cook

Write games, compose and play music, even explore electronics – it's easy as Pi! The Raspberry Pi offers a plateful of opportunities, and this great resource guides you step-by-step, from downloading, copying, and installing the software to learning about Linux and finding cool new programs for work, photo editing, and music. You'll discover how to write your own Raspberry Pi programs, create fun games, and much more! Open this book and find: What you can do with Python; Ways to use the Raspberry Pi as a productivity tool; How to surf the web and manage files; Secrets of Sonic Pi music programming; A guide to creating animations and arcade games; Fun electronic games you can build; How to build a 3D maze in Minecraft; How to play music and videos on your Raspberry Pi.

400 Pages Order code RPiDUM01 £17.99

RASPBERRY Pi MANUAL: A practical guide to the revolutionary small computer
176 pages Order code H001 £17.99

RASPBERRY Pi USER-GUIDE – Third Edition
262 pages Order code JW001 £16.99

PROGRAMMING THE RASPBERRY Pi
192 pages Order code MGH4 £10.99

GETTING STARTED WITH RASPBERRY Pi
164 pages Order code OR01 £11.50

TEACH-IN BOOKS

ELECTRONICS TEACH-IN 5

ELECTRONICS TEACH-IN 5

FREE CD-ROM

Jump Start – 15 design and build circuit projects dedicated to newcomers or those following courses in school and colleges. The projects are: Moisture Detector, Quiz Machine, Battery Voltage Checker, Solar-Powered Charger, Versatile Theft Alarm, Spooky Circuits, Frost Alarm, Mini Christmas Lights, iPod Speaker, Logic Probe, DC Motor Controller, Egg Timer, Signal Injector Probe, Simple Radio Receiver, Temperature Alarm.

PLUS:

PIC' N MIX – starting out with PIC Microcontrollers and PRACTICALLY SPEAKING – the techniques of project construction.

FREE CD-ROM – The free CD-ROM is the complete Teach-In 2 book providing a practical introduction to PIC Microprocessors plus MikroElektronika, Microchip and L-Tek PoScope software.

160 Pages **Order code ETI5** **£8.99**

ELECTRONICS TEACH-IN 6

ELECTRONICS TEACH-IN 6 –
A COMPREHENSIVE GUIDE TO RASPBERRY Pi
Mike & Richard Tooley

FREE CD-ROM

Teach-In 6 contains an exciting series of articles that provides a complete introduction to the Raspberry Pi, the low cost computer that has taken the education and computing world by storm.

This latest book in our Teach-In series will appeal to electronic enthusiasts and computer buffs wanting to get to grips with the Raspberry Pi.

Anyone considering what to do with their Pi, or maybe they have an idea for a project but don't know how to turn it into reality, will find Teach-In 6 invaluable. It covers: Programming, Hardware, Communications, Pi Projects, Pi Class, Python Quickstart, Pi World, Home Baking etc.

The book comes with a FREE cover-mounted DVDROM containing all the necessary software for the series so that readers can get started quickly and easily with the projects and ideas covered.

160 Pages **Order code ETI6** **£8.99**

ELECTRONICS TEACH-IN 7

ELECTRONICS TEACH-IN 7 – DISCRETE LINEAR CIRCUIT DESIGN
Mike & Richard Tooley

FREE CD-ROM

Teach-In 7 is a complete introduction to the design of analogue electronic circuits. Ideal for everyone interested in electronics as a hobby and for those studying technology at schools and colleges. Supplied with a free Cover-Mounted CDROM containing all the circuit software for the course, plus demo CAD software for use with the Teach-In series' Words for the cover; Discrete Linear Circuit Design* Understand linear circuit design* Learn with 'TINA' – modern CAD software* Design simple, but elegant circuits* Five projects to build: Pre-amp, Headphone Amp, Tone Control, VU-meter, High Performance Audio Power Amp PLUSAudio Out – an analogue expert's take on specialist circuitsPractically Speaking – the techniques of project building

160 Pages **Order code ETI7** **£8.99**

THE BASIC SOLDERING GUIDE HANDBOOK

LEARN TO SOLDER SUCCESSFULLY!
ALAN WINSTANLEY

The No.1 resource to learn all the basic aspects of electronics soldering by hand.

With more than 80 high quality colour photographs, this book explains the correct choice of soldering irons, solder, fluxes and tools. The techniques of how to solder and desolder electronic components are then explained in a clear, friendly and non-technical fashion so you'll be soldering successfully in next to no time! The book also includes sections on Reflow Soldering and Desoldering Techniques, Potential Hazards and Useful Resources. Plus a Troubleshooting Guide.

Also ideal for those approaching electronics from other industries, the Basic Soldering Guide Handbook is the best resource of its type, and thanks to its excellent colour photography and crystal clear text, the art of soldering can now be learned by everyone!

86 Pages **Order code AW1** **£9.99**

CHECK OUT OUR WEBSITE FOR MORE BOOKS
WWW.EPEMAG.COM

BOOK ORDER FORM

Full name: ....

Address: ....

....

....

.... Post code: .... Telephone No: ....

Signature: ....

☐ I enclose cheque/PO payable to DIRECT BOOK SERVICE for £ ....

☐ Please charge my card £ .... Card expiry date.......................................

Card Number ....

Valid From Date .... Card Security Code .... (The last three digits on or just below the signature strip)

Please send book order codes: ....

....

Please continue on separate sheet of paper if necessary

KCS TraceME

WORLDWIDE DISTRIBUTOR REQUESTS ARE WELCOME!

KCS always expands their distribution network worldwide. Please have a look at our company website for product details. We are only looking for financial strong distributors who understand our product line and programming scripts and can fully support their customers. Please feel free to send your distributor request. For KCS TraceME / LoRa Track & Trace product requests please fill in our web form.

www.Trace.ME

All trademarks mentioned herein belong to their respective owners.

PCB SERVICE

CHECK US OUT ON THE WEB

Basic printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are drilled and roller tinned, but all holes are a standard size. They are not silk-screened, nor do they have solder resist. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. **NOTE: PCBs from the July 2013 issue with eight digit codes** have silk screen overlays and, where applicable, are double-sided, plated through-hole, with solder masks, they are similar to the photos in the relevent project articles.

All prices include VAT and postage and packing. Add £2 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

PROJECT TITLE	ORDER CODE	COST
JAN '16		
Isolating High Voltage Probe For Oscilloscopes	04108141	£11.80
The Currawong – Part 3 – Remote Control Board	01111144	£6.95
FEB '16		
Spark Energy Meter – Main Board	05101151	£20.75
– Zener Diode Board	05101152	£7.50
– Calibrator Board	05101153	
APRIL '16		
Appliance Insulation Tester	04103151	£11.80
– Front Panel	04103152	£11.80
Low Frequency Distortion Analyser	04104151	£7.50
MAY '16		
2-Channel Balanced Input Attenuator for Audio Analysers and Digital Scopes		
– Main Board	04105151	£16.40
– Front Panel	04105152	£20.75
– Rear Panel	04105153	
Appliance Earth Leakage Tester		
– Main Board	04203151	£16.40
– Insulation Board	04203152	
– Front Panel	04203153	£16.40
4-Output Universal Voltage Regulator	18105151	£7.50
JUNE '16		
Infrasound Snooper	04104151	£7.50
Audio Signal Injector and Tracer	04106151	£9.64
– Shield Board	04106153	£7.48
– Demodulator Board	04106152	£5.36
Champion Preamp	01109121/22	£8.29
JULY '16		
Driveway Monitor – Detector Unit	15105151	£11.80
– Receiver Unit	15105152	£7.50
USB Charging Points	18107151	£5.00
AUG '16		
Low-cost Resistance Reference	04108151	£5.36
USB Power Monitor	04109121	£12.00
SEPT '16		
LED Party Strobe	16101141	£9.80
Speedo Corrector	05109131	£12.00
OCT '16		
Arduino-Based USB Electrocardiogram	07108151	£9.79
100W Switchmode/Linear Bench Supply – Part 2	18104141	£20.83
NOV '16		
Fingerprint Access Controller – Main Board	03109151	£12.88
– Switch Board	03109152	
DEC '16		
Universal Loudspeaker Protector	01110151	£12.88
9-Channel Infrared Remote Control	15108151	£16.42
Revised USB Charger	18107152	£5.36

PROJECT TITLE	ORDER CODE	COST
JAN '17		
High-performance Stereo Valve Preamplifier	01101161	£17.75
High Visibility 6-Digit LED Clock	19110151	£16.42
FEB '17		
Solar MPPT Charger/Lighting Controller	16101161	£17.75
Turntable LED Strobe	04101161	£7.60
MARCH '17		
Speech Timer for Contests & Debates	19111151	£16.42
APRIL '17		
Microwave Leakage Detector	04103161	£8.00
Arduino Multifunctional 24-bit Measuring Shield	04116011	£17.75
– RF Head Board	04116012	
Battery Pack Cell Balancer	11111151	£9.00
MAY '17		
The Micromite LCD BackPack	07102122	£11.25
Precision 230V/115V 50/60Hz Turntable Driver	04104161	£19.35
JUNE '17		
Ultrasonic Garage Parking Assistant	07102122	£10.45
Hotel Safe Alarm	03106161	£8.00
100dB Stereo LED Audio Level/VU Meter	01104161	£17.75

*** See NOTE left regarding PCBs with eight digit codes ***

Please check price and availability in the latest issue.
A large number of older boards are listed on, and can be ordered from, our website.
Boards can only be supplied on a payment with order basis.

Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

EPE SOFTWARE

Where available, software programs for *EPE* Projects can be downloaded free from the Library on our website, accessible via our home page at:
www.epemag.com

PCB MASTERS

PCB masters for boards published from the March '06 issue onwards are available in PDF format free to subscribers – email **fay.kearn@wimborne.co.uk** stating which masters you would like.

EPE PRINTED CIRCUIT BOARD SERVICE

Order Code **Project** **Quantity** **Price**

. . . .

Name . . . .

Address . . . .

. . . .

Tel. No. . . . .

I enclose payment of £ . . . . (cheque/PO in **£ sterling only**)

to: **Everyday Practical Electronics**

Card No. . . . .

Valid From . . . . Expiry Date . . . .

Card Security No. . . . .

Signature . . . .

Note: You can also order PCBs by phone, Fax or Email or via the Shop on our website on a secure server:
http://www.epemag.com

CLASSIFIED
ADVERTISEMENTS

If you want your advertisements to be seen by the largest readership at the most economical price our classified page offers excellent value. The rate for semi-display space is £10 (+VAT) per centimetre high, with a minimum height of 2·5cm. All semi-display adverts have a width of 5.5cm. The prepaid rate for classified adverts is 40p (+VAT) per word (minimum 12 words).

All cheques, postal orders, etc., to be made payable to Everyday Practical Electronics. **VAT must be added**. Advertisements, together with remittance, should be sent to Everyday Practical Electronics Advertisements, 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU. Phone: 01202 880299. Fax: 01202 843233. Email: stewart.kearn@wimborne.co.uk. For rates and information on display and classified advertising please contact our Advertisement Manager, Stewart Kearn as above.

Everyday Practical Electronics reaches more UK readers than any other UK monthly hobby electronics magazine, our sales figures prove it.

We have been the leading monthly magazine in this market for the last twenty-seven years.

BOWOOD ELECTRONICS LTD
Suppliers of Electronic Components
www.bowood-electronics.co.uk
Unit 10, Boythorpe Business Park, Dock Walk, Chesterfield, Derbyshire S40 2QR. Sales: 01246 200 222
Send large letter stamp for Catalogue

WEARDALE ELECTRONICS
FOR ELECTRONIC COMPONENTS & ELECTRICAL PARTS Etc.
SEND YOUR WANTS LIST TO
steve@weardale-electronics.co.uk
or BROWSE MY EBAY SHOP AT
http://stores.ebay.co.uk/weardaleelectronics
NO ORDER TOO SMALL – PERSONAL SERVICE

ELECTRONIC & HARDWARE COMPONENTS
EVERYTHING FOR THE HOME CONSTRUCTOR
www.partridgeelectronics.co.uk

CANTERBURY WINDINGS
UK manufacturer of toroidal transformers
(10VA to 3kVA)
All transformers made to order. No design fees.
No minimum order.
www.canterburywindings.co.uk
01227 450810

MISCELLANEOUS

KITS, TOOLS, COMPONENTS. S.A.E. Catalogue. SIR-KIT ELECTRONICS, 52 Severn Road, Clacton, CO15 3RB, **http://sir-kit.webs.com**

PIC DEVELOPMENT KITS, DTMF kits and modules, CTCSS Encoder and Decoder/Display kits. Visit **www.cstech.co.uk**

VALVES AND ALLIED COMPONENTS IN STOCK. Phone for free list. Valves, books and magazines wanted. Geoff Davies (Radio), tel. 01788 574774.

If you would like to advertise on the Classified page then please call Stewart Kearn on:

01202 880299

or email stewart.kearn@wimborne.co.uk

ADVERTISERS INDEX

BINARY DISTRIBUTION . . . . Cover (ii)
BRUNNING SOFTWARE 46
CRICKLEWOOD ELECTRONICS 59
ESR ELECTRONIC COMPONENTS 6
FUZE TECHNOLOGIES . . . . Cover (ii)
HAMMOND ELECTRONICS Ltd 23
iCSAT 72
JPG ELECTRONICS 72
KCS 69
LASER BUSINESS SYSTEMS 37
MICROCHIP . . . . Cover (iii), 10 & 55
PEAK ELECTRONIC DESIGN . . . . Cover (iv)
PICO TECHNOLOGY 49
POLABS D.O.O. 37
QUASAR ELECTRONICS 2/3
STEWART OF READING 59
TAG-CONNECT 62

ADVERTISEMENT OFFICES:
113 LYNWOOD DRIVE, MERLEY, WIMBORNE,
DORSET BH21 1UU
PHONE: 01202 880299
FAX: 01202 843233
EMAIL: stewart.kearn@wimborne.co.uk
WEB: www.epemag.com
For editorial address and phone numbers see page 7

Next Month

Content may be subject to change

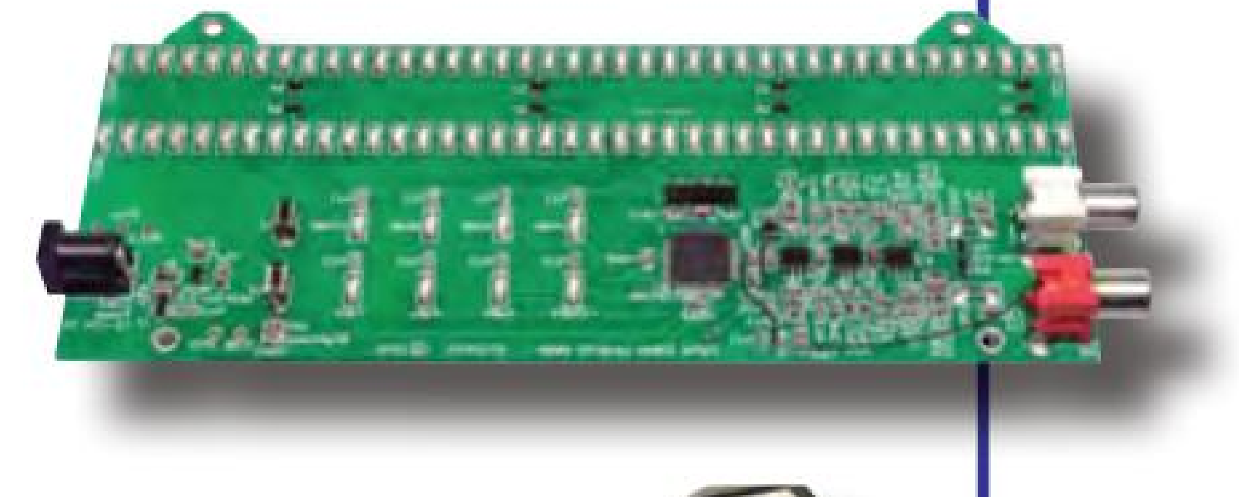
Brownout Protector for Induction Motors

Brownouts occur when the mains voltage drops to a very low level, causing incandescent lamps to be very dim or 'brown'. Brownouts can cause induction motors to burn out because they cannot start properly. This superb project monitors the AC mains voltage and disconnects power to the appliance when the voltage drops below a preset level, only reconnecting it when the voltage returns to its normal level.

SYDNEY (EST)
Tues
17 May

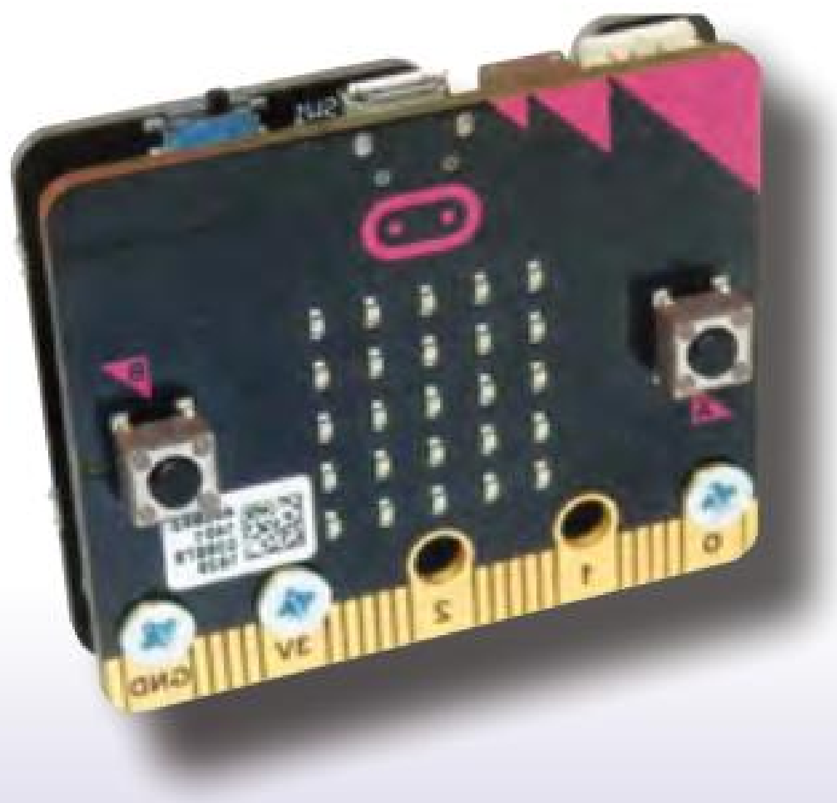
Micromite-Based Super Clock

Yes, we can guess what you are thinking... not another clock project! But this one is special because it can show the time using either an analogue or digital display. It can also track the time in up to 20 different locations, adjust each location for daylight saving and keep precise time using either a temperature-compensated real-time clock (RTC) module or a GPS module.



100dB Stereo LED Audio Level/VU Meter – Part 2

In June, we introduced our new *Audio Level/VU Meter* which uses 80 high-brightness SMD LEDs to give a colourful dual-bargraph display showing average and/or peak audio levels. This article deals with assembling it and explains how to set it up and use it.



Teach-In 2017: Introducing the BBC micro:bit – Part 2

In part 2 of *Teach-In 2017*, Mike Tooley explores the Mu editor, delves into some of the complexities of the MicroPython language and takes a detailed at the micro:bit's I/O capability. Our practical project takes the form of an electronic spirit level.

PLUS!

All your favourite regular columns from *Audio Out* and *Circuit Surgery* to *Electronic Building Blocks*, *PIC n' Mix* and *Net Work*.

JULY '17 ISSUE ON SALE 1 JUNE 2017

WELCOME TO JPG ELECTRONICS

Selling Electronics in Chesterfield for 29 Years

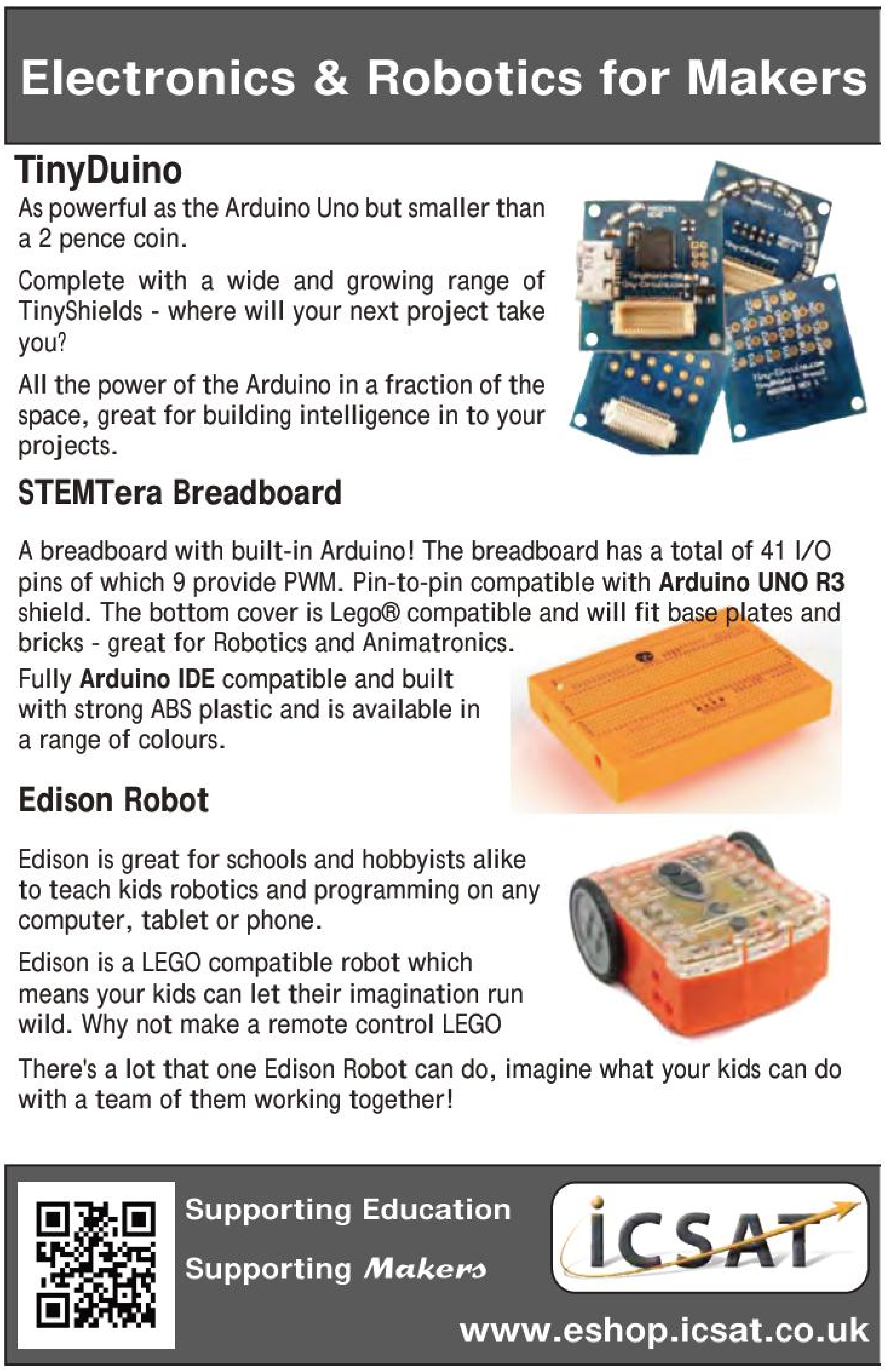
Open Monday to Friday 9am to 5:30pm
And Saturday 9:30am to 5pm

- Aerials, Satellite Dishes & LCD Brackets
- Audio Adaptors, Connectors & Leads
- BT, Broadband, Network & USB Leads
- Computer Memory, Hard Drives & Parts
- DJ Equipment, Lighting & Supplies
- Extensive Electronic Components
  - *ICs, Project Boxes, Relays & Resistors*
- Raspberry Pi & Arduino Products
- Replacement Laptop Power Supplies
- Batteries, Fuses, Glue, Tools & Lots more...

T: 01246 211 202
E: sales@jpgelectronics.com
JPG Electronics, Shaw's Row,
Old Road, Chesterfield, S40 2RB
W: www.jpgelectronics.com

JPG Electronics

Retail & Trade Welcome • Free Parking • Google St View Tour: S40 2RB


Electronics & Robotics for Makers

TinyDuino

As powerful as the Arduino Uno but smaller than a 2 pence coin.

Complete with a wide and growing range of TinyShields - where will your next project take you?

All the power of the Arduino in a fraction of the space, great for building intelligence in to your projects.

STEMTera Breadboard

A breadboard with built-in Arduino! The breadboard has a total of 41 I/O pins of which 9 provide PWM. Pin-to-pin compatible with **Arduino UNO R3** shield. The bottom cover is Lego® compatible and will fit base plates and bricks - great for Robotics and Animatronics.

Fully **Arduino IDE** compatible and built with strong ABS plastic and is available in a range of colours.

Edison Robot

Edison is great for schools and hobbyists alike to teach kids robotics and programming on any computer, tablet or phone.

Edison is a LEGO compatible robot which means your kids can let their imagination run wild. Why not make a remote control LEGO

There's a lot that one Edison Robot can do, imagine what your kids can do with a team of them working together!

Supporting Education
Supporting *Makers*

iCSAT

www.eshop.icsat.co.uk

Published on approximately the first Thursday of each month by Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Printed in England by Acorn Web Offset Ltd., Normanton, WF6 1TW. Distributed by Seymour, 86 Newman St., London W1T 3EX. Subscriptions INLAND: £23.50 (6 months); £43.00 (12 months); £79.50 (2 years). EUROPE: airmail service, £28.00 (6 months); £52.00 (12 months); £99.00 (2 years). REST OF THE WORLD: airmail service, £37.00 (6 months); £70.00 (12 months); £135.00 (2 years). Payments payable to "Everyday Practical Electronics", Subs Dept, Wimborne Publishing Ltd. Email: subs@epemag.wimborne.co.uk. EVERYDAY PRACTICAL ELECTRONICS is sold subject to the following conditions, namely that it shall not, without the written consent of the Publishers first having been given, be lent, resold, hired out or otherwise disposed of by way of Trade at more than the recommended selling price shown on the cover, and that it shall not be lent, resold, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover by way of Trade or affixed to or as part of any publication or advertising, literary or pictorial matter whatsoever.

Development Tool of the Month!

Explorer 16/32 Development Board

Part Number
DM240001-2

Overview:

The Explorer 16/32 Development Board is a flexible development system for Microchip's 16-bit and 32-bit PIC® microcontrollers. It is a refreshed and cost-effective version of Explorer 16 Development Board (DM240001) with several new features. This board supports devices from the PIC24 and PIC32 MCU families and dsPIC® DSC families as Processor Plug-In Modules (PIMs), allowing you to develop various applications quickly. The Explorer 16/32 Development Board is completely backwards compatible with the Classic Explorer 16 Development Board (DM240001 and DM240002) and its associated ecosystem.

Key Features:

- 100-pin plug-in module socket
- Integrated PICkit™-On-Board (PKOB) Programmer/Debugger
- MPLAB® ICD3 and MPLAB REAL ICE™ In-Circuit Debugger/ Programmer support for advanced operations
- Multiple power options
- On board USB to UART/I²C™ adapter for data exchange with PC/Mac/Linux based host Wide ecosystem with mikroBUS™, PICtail™ Plus and Pmod™ interfaces
- Alpha-numeric 16 x 2 LCD display, 8x User LEDs, 4x Push Buttons, 10k Potentiometer

Order Your Explorer 16/32 Development Board Today at:

www.microchipdirect.com

The Microchip name and logo, PIC and MPLAB are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries. All other trademarks mentioned herein are the property of their respective companies.
© 2016 Microchip Technology Inc. All rights reserved. MEC2122Eng10/16

PEAK®
electronic design ltd

2 Year Warranty as standard

UK designed and manufactured

Atlas DCA - Semiconductor Analyser model DCA55

Now with backlit display and AAA battery!

atlas DCA
model DCA55
PEAK®
electronic design ltd
AAA Battery Edition
Base-Emitter V
VBE=1.039V
semiconductor component analyser
automatic lead identification
on - test
scroll - off
warning: avoid charge/voltages

103 x 70 x 20mm

- Connect any way round.
- Automatically identify component type.
- Automatically identify pinouts.
- Supports Transistors, MOSFETs, Diodes, LEDs and more.
- Measure transistor gain (h_{FE}).
- Measure V_{BE} (now 1mV resolution!)
- Measure leakage current.
- Measure MOSFET thresholds.
- Measure LED voltages.

Designed in the UK and made in the UK.

Just a few example screen shots:

```
PNP Germanium
Transistor      ↓
RED GREEN BLUE
Emit Coll Base  ↓
Current gain
hFE=67          ↓
Test current
IC=2.50mA       ↓
Base-Emitter V
VBE=0.293V      ↓
Test current
IB=4.981mA      ↓
Leakage current
IC=0.027mA      ↓
```

```
NPN Silicon
Transistor      ↓
RED GREEN BLUE
Base Emit Coll  ↓
Current gain
hFE=117         ↓
Test current
IC=2.50mA       ↓
Base-Emitter V
VBE=0.711V      ↓
Test current
IB=4.583mA      ↓
Leakage current
IC=0.000mA      ↓
```

```
PNP Darlington
Transistor      ↓
RED GREEN BLUE
Emit Base Coll  ↓
Diode protection
between C-E     ↓
Current gain
hFE=9124        ↓
Test current
IC=2.50mA       ↓
Base-Emitter V
VBE=1.321V      ↓
Test current
IB=3.720mA      ↓
Leakage current
IC=0.000mA      ↓
```

```
Enhancement mode
N-Ch MOSFET     ↓
RED GREEN BLUE
Gate Drn  Srce  ↓
Gate Threshold
VGS=3.47V       ↓
Test current
ID=2.50mA       ↓

Diode or diode
junction(s)     ↓
RED GREEN BLUE
Anod Cath       ↓
Forward voltage
VF=0.694V       ↓
Test current
IF=4.663mA      ↓
```

```
Three terminal
bicolour LED    ↓
Pinout for D1
                ↓
RED GREEN BLUE
      Anod Cath ↓
Forward voltage
D1 VF=1.983V    ↓
Test current
D1 IF=3.223mA   ↓
Pinout for D2
                ↓
RED GREEN BLUE
Anod      Cath  ↓
Forward voltage
D2 VF=1.927V    ↓
Test current
D2 IF=3.281V    ↓
```

Universal test clips for large and small components

Available direct from us and from our distributors:

RS
The electronics specialist maplin
Rapid electronics
Farnell

Peak Direct Price:

£48.00

(£40.00+VAT)

Peak's insured UK delivery £3.00 inc. VAT

It's only possible to show summary specifications here. Please ask if you'd like detailed data. Further information is also available on our website. Product price refunded if you're not happy.

E&OE

Tel. 01298 70012
www.peakelec.co.uk
sales@peakelec.co.uk

Atlas House, 2 Kiln Lane
Harpur Hill Business Park
Buxton, Derbyshire
SK17 9JL, UK

Follow us on twitter for tips, tricks and news.
@peakatlas